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● PROJECTS ● THEORY ●
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● POPULAR FEATURES ●
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EPE EVERYDAY PRACTICAL ELECTRONICS

INCORPORATING ELECTRONICS TODAY INTERNATIONAL

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Our November 2012 issue will be published on Thursday 4 October 2012, see page 80 for details.

Projects and Circuits

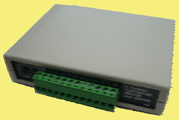
Series and Features

Regulars and Services

Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

4-Channel Serial Port Temperature Monitor & Controller Relay Board

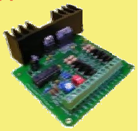


4 channel computer serial port temperature monitor and relay controller with four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay channels provide output control. Relays are independent of sensor channels, allowing flexibility to setup the linkage in any way you choose. Commands for reading temperature and relay control sent via the RS232 interface using simple text strings. Control using a simple terminal / comms program (Windows HyperTerminal) or our free Windows application software.
Kit Order Code: 3190KT - **£84.95**
Assembled Order Code: AS3190 - **£99.95**

40 Second Message Recorder

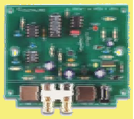
Feature packed non-volatile 40 second multi-message sound recorder module using a high quality Winbond sound recorder IC. Standalone operation using just six onboard buttons or use onboard SPI interface. Record using built-in microphone or external line in. 8-24 Vdc operation. Just change one resistor for different recording duration/sound quality. sampling frequency 4-12 kHz.
Kit Order Code: 3188KT - **£29.95**
Assembled Order Code: AS3188 - **£37.95**
120 second version also available

Bipolar Stepper Motor Chopper Driver



Get better performance from your stepper motors with this dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase set using on-board potentiometer. Rated to handle motor winding currents up to 2 Amps per phase. Operates on 9-36Vdc supply voltage. Provides all basic motor controls including full or half stepping of bipolar steppers and direction control. Allows multiple driver synchronisation. Perfect for desktop CNC applications.
Kit Order Code: 3187KT - **£39.95**
Assembled Order Code: AS3187 - **£49.95**

Video Signal Cleaner



Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors.
Kit Order Code: K8036KT - **£29.95**
Assembled Order Code: VM106 - **£44.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

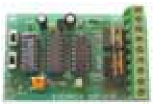
DC Motor Speed Controller (100V/7.5A)

Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
Kit Order Code: 3067KT - **£19.95**
Assembled Order Code: AS3067 - **£27.95**

Bidirectional DC Motor Speed Controller

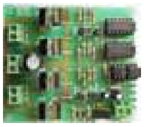
Control the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.
Kit Order Code: 3166v2KT - **£23.95**
Assembled Order Code: AS3166v2 - **£33.95**

Computer Controlled / Standalone Unipolar Stepper Motor Driver



Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - **£17.95**
Assembled Order Code: AS3179 - **£24.95**

Computer Controlled Bi-Polar Stepper Motor Driver



Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm.
Kit Order Code: 3158KT - **£24.95**
Assembled Order Code: AS3158 - **£34.95**

AC Motor Speed Controller (600W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or 230V AC single phase induction motor rated up to 600 Watts. Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors.
Kit Order Code: 1074KT - **£15.95**
Assembled Order Code: AS1074 - **£23.95**

See www.quasarelectronics.com for lots more DC, AC and Stepper motor drivers

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Order Code EPL500 - **£179.95**
Also available: 30-in-1 **£17.95**, 50-in-1 **£29.95**, 75-in-1 **£39.95** £130-in-1 **£49.95** & 300-in-1 **£79.95** (see website for details)

Tools & Test Equipment

We stock an extensive range of soldering tools, test equipment, power supplies, inverters & much more - please visit website to see our full range of products.

Advanced Personal Scope 2 x 240MS/s

Features 2 input channels - high contrast LCD with white backlight - full auto set-up for volt/div and time/div - recorder roll mode, up to 170h per screen - trigger mode: run - normal - once - roll ... - adjustable trigger level and slope and much more.
Order Code: APS230 - ~~£499.95~~ **£394.95**

Personal Scope 10MS/s

The Personal Scope is not a graphical multimeter but a complete portable oscilloscope at the size and the cost of a good multimeter. Its high sensitivity - down to 0.1mV/div - and extended scope functions make this unit ideal for hobby, service, automotive and development purposes. Because of its exceptional value for money, the Personal Scope is well suited for educational use.
Order Code: HPS10 - ~~£189.95~~ **£139.95**

See website for more super deals!

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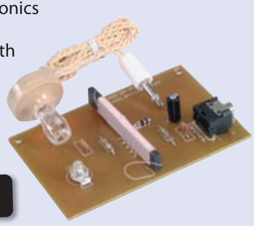
POPULAR Kits for Electronic Enthusiasts

Audio Kits

Crystal Radio
Cat. KV-3540

Enjoy AM broadcasting without using battery or other power sources. Ideal for entry-level students or hobbyist with little electronics experience. Includes circuit explanation. Kit supplied with silk-screened PCB, crystal, prewound coil, earphone and all components.

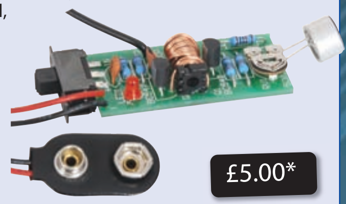


• PCB: 81 x 53mm

£4.75*

Miniature FM Transmitter
Cat. KE-4711

This unit is a two transistor two stage transmitter that has the benefits of being VERY COMPACT. Kit contains PCB, 9V battery and components, and makes an ideal, inexpensive beginners kit.



• 9VDC
• PCB: 45 x 23mm

£5.00*

Jacob's Ladder High Voltage Display Kit MK2
Cat. KC-5445

With this kit and the purchase of a 12V ignition coil (available from auto stores and parts recyclers), create an awesome rising ladder of noisy sparks that emits the distinct smell of ozone. This improved circuit is suited to modern high power ignition coils and will deliver a spectacular visual display. Kit includes PCB, pre-cut wire/ladder and electronic components.

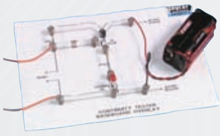
£15.75*

• 12V car battery, 7Ah SLA or > 5A DC power supply required
• PCB: 170 x 76mm

THOUSANDS SOLD!

Short Circuits - Volume 1

This volume will teach you everything you need to get started in electronics and is suitable for ages 8+. We give you the option of buying the book on its own, or together with the accompanying kit that contains the components for each of the 20-odd projects described in the book. Some of the exciting projects include a Police Siren, Electronic Organ, Sound Effects Unit, Light Chaser and many, many more! The full colour 96 page book, is lavishly illustrated with over 100 drawings and diagrams. No prior knowledge of electronics is needed, projects are fun and safe to build.



Short Circuits Book
BJ-8502 £3.75

Short Circuits Project Kit
KJ-8504 £12.50

Short Circuits Book and Project Kit
KJ-8502 £14.50

IR Remote Extender MKII Kit
Cat. KC-5432

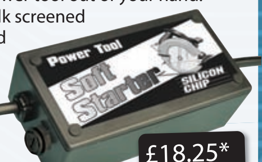
Operate your DVD player or digital decoder using its remote control from another room. It picks up the signal from the remote control and sends it via a 2-wire cable to an infrared LED located close to the device. Features fast data transfer, capable of transmitting Foxtel digital remote control signals using the Pace 400 series decoder. Kit supplied with case, screen printed front panel, PCB with overlay and all electronic components.

• Required: 9VDC and 2-wire cable for extending the IR-Tx lead (use WB-1702 £0.17 per metre)
• PCB: 79 x 47mm

£10.00*

Soft Start Kit for Power Tools
Cat. KC-5511

Stops that dangerous kick-back when you first power up an electric saw, router or other mains-powered hand tool. This helps prevent damage to the job or yourself when kick-back torque jerks the power tool out of your hand. Kit supplied with PCB, silk screened case, 2m power cord and all specified electronic components.



• 240VAC 10A
• PCB: 81 x 59mm

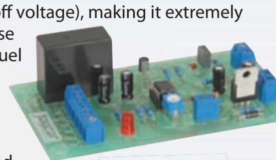
NOTE: Requires UK mains power cord.

£18.25*

Universal Voltage Switch
Cat. KC-5377

POPULAR KIT!

A universal module suits a range of different applications. It will trip a relay when a preset voltage is reached. Can be configured to trip with a rising or falling voltage making it suitable for a wide variety of voltage outputting devices eg., throttle position sensor, air flow sensor, EGO sensor. It also features adjustable hysteresis (the difference between trigger on/off voltage), making it extremely versatile. You could use it to trigger an extra fuel pump under high boost, anti-lag wastegate shutoff, and much more. Kit supplied with PCB, and electronic components.

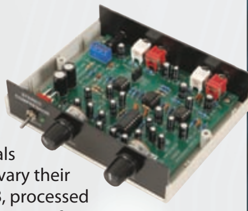


£12.00*

• PCB size: 105 x 60mm

Stereo Compressor Kit
Cat. KC-5507

Compressors are useful in eliminating the extreme sound levels during TV ads, "pops" from microphones when people speak or bump / drop them, levelling signals when singers or guitarist vary their level, etc. Kit includes PCB, processed case and electronic components for 12VDC operation. 12VDC plug pack required - use MP-3147 £6.25.



• PCB: 118 x 102mm

£21.75*

Digital Audio Delay Kit
Cat. KC-5506

Corrects sound and picture synchronization ("lip sync") between your modern TV and home theatre system. Features an adjustable delay from 20 to 1500ms in 10ms steps, and handles Dolby Digital AC3, DTS and linear PCM audio with sampling rate of up to 48kHz. Connections include digital S/PDIF and optical Toslink connections, and digital processing means there is no audio degradation. Kit includes PCB with overlay and pre-soldered SMD IC, enclosure with machined panels, and electronic components.

• 9-12VDC power supply required
• Universal IR remote required
• PCB: 103 x 118mm

£36.25*

DAB+/FM Digital Radio Kit
Cat. KC-5491

Many Hi-Fi enthusiasts want to add a digital tuner to their system and want great function and sound quality. This unit covers DAB+ and FM, has analogue and optical audio outputs, IR remote (included), an external antenna connector and is powered by mains plugpack. The kit is complete with everything, including the case. See website for full specs.

• Digital station info display
• RCA and optical audio output
• External antenna connection
• Station memory presets
• Display and control PCB: 277 x 57mm

£144.75*

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Made to measure

It's August (as I write this) – summertime – and news is a little slow, so I thought I'd share an amusing item that I recently came across in Wikipedia.

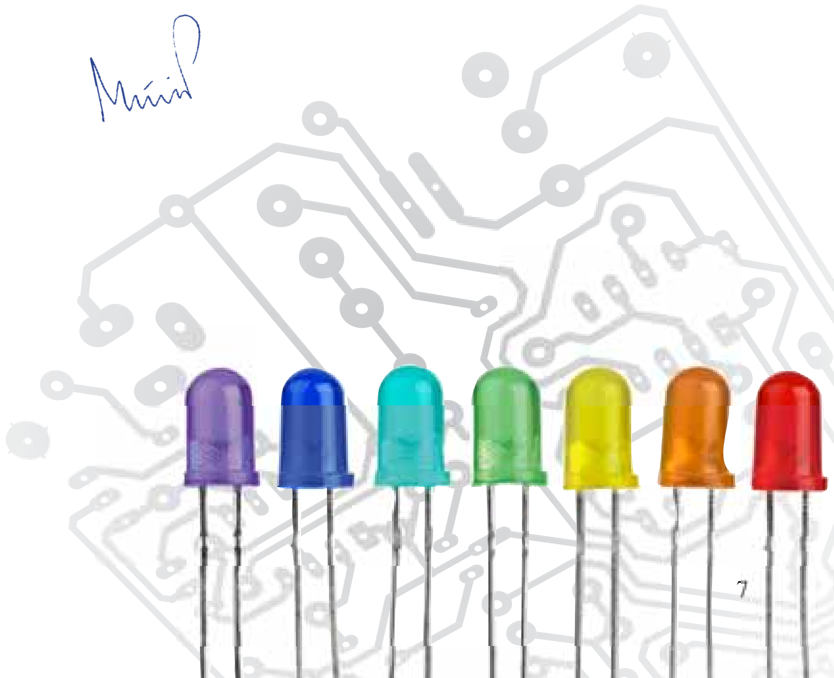
Letters in *Readout* earlier this year covered issues around units, particularly the SI system, or the metric system to give it its less formal name. To master the SI system you need to be familiar with basic units (for example, metre or amp) and a collection of prefixes that multiply or divide the unit by factors of ten, giving us microamps, kilometres and a good range of other measurement sizes, ranging from the minute to the enormous. At present, the highest official prefix is 'yotta' or 10^{24}. You might think yotta is uselessly enormous; but if you weighed the earth's oceans, they would weigh about 1.4Yg, that is 1.4 yottagrams. Need to know the power output of the sun? Well, you'll need a pretty big meter, one that measures YW, since the sun's output is 385YW (the pleasingly rhythmic 'yottawatt').

Clearly yotta is very large, but not so large that we have no use for it. In fact, for some it's not big enough and the joke prefix 'hella', as in 'a hell of a lot' has started to be used. Its use may not be completely serious, but Internet search engine giant Google has got behind a campaign in California to make hella an official SI prefix representing 10^{27}, or a septillion. If you type hellasecond or hellametre into Google it will give you sensible responses – apparently the diameter of the universe is a bit over a hellameter.

Perhaps Google are running out of prefixes to indicate the size of storage in their servers and have their eyes on a 'hellabyte'. I'm sure there's room for more fun with prefixes or units, do readers have any suggestions for amusing new names or combinations?

Your next slice of Pi

Pi and PIC fans will notice that this month's issue doesn't include our regular *Pic n' Mix* or *Raspberry Pi* pieces. Mike Hibbett, our microcontroller guru who writes these pieces, has been unable to put pen to paper this month, but rest assured, Mike will be back next month.



NEWS

A roundup of the latest Everyday News from the world of electronics

Super Hi-Vision – special Olympic report by Barry Fox

At a live demonstration in a private viewing theatre at the BBC's Broadcasting House in London, Matthew Postgate, BBC's controller of R&D, introduced Super Hi-Vision (SHV) as 'the future of television.'

'Super Hi-Vision began as an idea talked about over a dinner at NHK's labs in Japan between NHK and BBC engineers in May 2009' said Dr Keiichi Kubota, head of science and technology research laboratories at NHK.

'Every piece of equipment we have built is now here in London with a crew of twenty, and over the next three weeks we are putting it all to the test. What you are seeing now is only the fourth ever live multi-camera Super Hi-Vision transmission.'

NHK's hardware was assembled at the Olympic Park in East London for use by the BBC and Olympic Broadcasting Services (set up by the International Olympic Committee in 2001) to make live transmissions and recordings in SHV. The SHV signal was carried by 'Janet', the UK's research and education 100Gbit/sec 5000km optic fibre network, to public viewing theatres in Glasgow (Pacific Quay), Bradford (National Media Museum) and London (Olympic Park Broadcast Centre). International networks relayed the signal to theatres in Tokyo, Fukushima and Washington DC.

SHV technology

Although 142 cameras were used for conventional HD cover of the Opening Ceremony, the SHV version was shot with just three SHV native 8k cameras, made for NHK by Ikegami. These cameras use four 4k image sensors, one red, one blue and two green, with the two green sensors offset horizontally and vertically by half a pixel. The eye is most sensitive to green light, so signal processing lets the four sensors generate an image with full 8k resolution (albeit with diagonal resolution slightly reduced).

NHK is now developing prototype cameras with three native 8k sensors, but these were not ready for use at the London Games.

The SHV cameras in London were operating at a frame rate of 60fps progressive. The BBC had suggested that NHK increase this to 300fps for greater fluidity of motion, but increasing the sensor native speed to 300Hz would reduce the sensor's light sensitivity.

This would require the use of a larger sensor, which in turn decreases the depth of (focus) field – making the camera hard to use for sports live action. NHK is now working on 120Hz as a compromise, with the option to add a shutter that chops the light at 300Hz.

The 22.2 sound system uses a stereo sub-woofer pair, with 22 speakers arranged generally in the pattern of three seven-channel horizontal setups, stacked vertically and with an extra speaker directly overhead. During system installation for the Games, all 24 channels had to be checked to ensure that channel one at the Park, matched speaker one in all the viewing theatres, and so on.

The BBC used a JVC D-ILA (direct-drive image light amplification) 8k projector for the screening, along with a Sharp 85-inch 8k LCD display in the theatre lobby.

Superb quality

After a 25-minute edited highlights recording of the opening ceremony, shot with three SHV cameras, we watched a live feed from the Aquatics Centre coming from two SHV cameras. In each case, the BBC had deliberately not added any voice-over, relying solely on the live commentary, which the spectators were hearing at the event venue.

A Sharp 85-inch LCD display used to show NHK's Super Hi-Vision coverage of the London 2012 Olympics

One of three Ikegami SHV cameras used for the Olympic Opening ceremony. 142 'ordinary' HD cameras were used for conventional coverage

For the first time, I was able to view a huge TV screen as a landscape with my eyes free to wander over a wide expanse of image. The picture was so sharp, even for night-time stadium shots, that it was easy to identify VIPs in the audience.

Said Tim Plyming, project lead for the BBC's SHV trial. 'We have found that some of our senior executives like to stand in front of the screen and get someone to take their picture, because it looks as if they were there at the stadium'.

The BBC took the opportunity to stage a small exhibition of Olympic broadcast history. This proved a depressing sight. The only surviving EMI Emitron camera used at the 1948 London Olympic Games reminded of how EMI was once a pathfinder in electronics; and the first Sony HDC-100 HHDTV camera used at the Los Angeles 1984 Olympics reminded of how Japan took over.

A reminder of when Britannia ruled the electromagnetic waves, or at least was a serious contender. Shown above is an EMI CPS Emitron camera, Model 4499. This camera was first used in a three-camera outside broadcast van on the 29 July 1948 at the Wembley Olympic Games. It was innovative in using a new type of camera tube called a CPS (cathode potential stabilised) Emitron tube, which gave better pictures. It was also one of the first television cameras to feature an electronic viewfinder.

Nook e-readers coming to the UK

When it comes to e-readers, the choice in the UK has been pretty much between Amazon's Kindle range and Apple's more powerful, but heavier and more expensive iPad. This looks likely to change with the announcement from Barnes and Noble that they plan to launch their 'Nook' range of e-readers in the UK. Barnes and Noble are, by some margin, the largest bookshop retailer in the US and a direct competitor with Amazon.

Like the Kindle range, the Nooks come in a variety of tablet models, and in the UK, Barnes and Noble have stated that the initial launch models will be the Nook 'Simple Touch' and the 'Simple Touch with GlowLight'. The Simple Touch features an 800 × 600 E-ink touch screen, with 802.11 b/g/n Wi-Fi and a USB port for charging and connecting to a computer. It can hold an estimated 1000 books.

The memory options are flexible, microSD and microSDHC memory cards can be inserted to expand Simple Touch's memory from the installed 2GB to up to 32GB.

Supported file formats include EPUB (DRM and non-DRM), PDF, jpeg, gif,

The Nook, a new option for UK e-reader users

png, and bmp, which means that you can read your favourite PDF-based electronics magazine on the Nook.

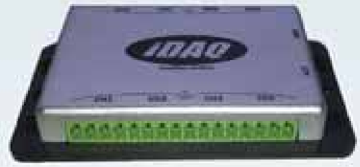
Barnes and Noble are aiming for an autumn launch, when UK customers will be able to shop at the Nook Store for 'more than 2.5 million digital titles – including top-selling UK books, newspapers and magazines – plus comics, exciting NOOK Apps and more.' Further details are promised at: **www.nook.co.uk**

Free panel design software

Beta Layout, in co-operation with German firm Ing. Büro Friedrich, is offering free, fully functional layout software with which you can easily design your own electronic project front panels. The software works with PCs running Win9X/ Win2000/WinXP/WinVista/Win7 and is available for download from ***www.panel-pool.com/fpuk/service_downloads.html***

The software allows users to specify internal cutouts, deep milling. countersunk drilling, threading, text engraving and digital image printing in colour. The output files are compatible with Beta's panel fabrication service, enabling users to quickly and easily design a panel and get it fabricated to professional standards.

iDAQ – SMART data 'grabbers'



Now available from Audon Electronics is the new iDAQ range of Wi-Fi-enabled dataloggers. The iDAQ range comprises voltage input, 4-20mA input, PT100 thermometer input, and combination voltage and pulse counter input units in both four and eight-channel versions.

The data loggers offer high resolution, high accuracy readings and are compatible with a wide range of analogue and digital sensors. iDAQ units have Wi-Fi connectivity and incorporate a built-in web-server, so no PC application software is required.

Readings can be viewed in real time in tabular or chart recorder format using any tablet, PC or mobile device via a web browser. Readings can also be logged in the internal 256kb memory for download later. Log rates from once every five seconds to every 24 hours can be set. See: **www.audon.co.uk**

SPIRATRONICS GO FOR GOLD

Low-quantity component supplier Spiratronics is one of six UK companies to have been shortlisted for a prestigious Nectar Business Award. It is in recognition of their utilisation of technology in building a bespoke computer system to service their customer's needs that Spiratronics has been nominated.

The winner of the award will be judged by a panel of business experts including Karren Brady, star of BBC Television's The Apprentice.

By NICHOLAS VINEN

Two TOSLINK–S/PDIF Audio Converters

Do you have a DVD or CD player with a TOSLINK (optical) output but only coaxial S/PDIF inputs on your amplifier? Or do you have the opposite problem? What about hum from your speakers when running digital audio via a coaxial cable? With these simple converters you can easily solve these problems.

TWO different circuits are described here: (1) an *S/PDIF to TOSLINK Converter*; and (2) a *TOSLINK to S/PDIF Converter*. The first converts a S/PDIF (coaxial) signal to an optical signal, while the second does the opposite. Each converter is built on a separate circuit board and is powered via a small AC or DC plugpack supply.

Transmitting audio digitally is great because in most cases there is no signal degradation. The best transmission medium is optical fibre (ie, TOSLINK) because the two connected devices remain electrically isolated. However, it's not without its drawbacks – the cables tend to be expensive and can not be cut to length.

Also, because there are multiple competing standards (coaxial, TOSLINK and HDMI to name three), you won't always have the same connectors at both ends.

In fact, these issues are so common that several staff members were in the market for digital audio converters. They are commercially available, but the retail cost of around £50 for a bidirectional unit seems high, considering that we can put together something similar for much less than that.

Advantages

With these designs, you can build just one converter or several, depending on your exact requirements. They are designed to be housed inside heatshrink plastic tubing, so there is no need to drill a box, and this keeps the unit cost low as well as simplifying the board shape. Plus, these designs

Digital Audio Signal Formats

The digital audio signals found in domestic equipment are all in the form of S/PDIF (Sony/Philips Digital Interface) bitstreams – either as 400mV electrical signals sent along 75Ω coaxial cables or, as optical signals (pulses of 660nm red light) sent along fibre-optic cables. The optical signal form is often called 'TOSLINK'.

Although domestic digital bitstream audio is split almost equally between the coaxial and optical forms, they're both virtually identical in terms of the encoding and serialisation used. So it's relatively easy to convert between the two, in either direction.

can be powered from a wide range of plugpacks, so chances are you already have a suitable power supply spare from another piece of equipment. They also use little power, making it easy to run several from a single plugpack.

In addition, TOSLINK modules from both Jaycar and Altronics can be used – in fact virtually any are suitable. Some modules require a 3V supply and some a 5V supply. Only a few resistors in the on-board regulator circuit need to be changed to suit either type.

This is the *S/PDIF to TOSLINK Converter* board. It accepts digital audio at the RCA phono socket at left and outputs an optical signal at the TOSLINK transmitter at right. Power is fed in via the on-board socket at top left.

The companion *TOSLINK to S/PDIF Converter* works the other way – ie, it converts an optical signal to a S/PDIF signal and outputs it at the RCA phono socket at right.

Rather than mount them in a case, the converter boards can be sleeved in heatshrink and hidden behind the A/V equipment they connect to.

Uses

The most obvious use for a digital audio converter is when you want to connect two pieces of equipment and one has a TOSLINK connector, while the other has a coaxial socket. However, there is another purpose; when either converter is used, the two pieces of equipment will be electrically isolated. This means that as long as you are careful to avoid unintentionally connecting multiple signal earths via the converter power supply, an earth loop cannot be formed, regardless of the connection method at either end.

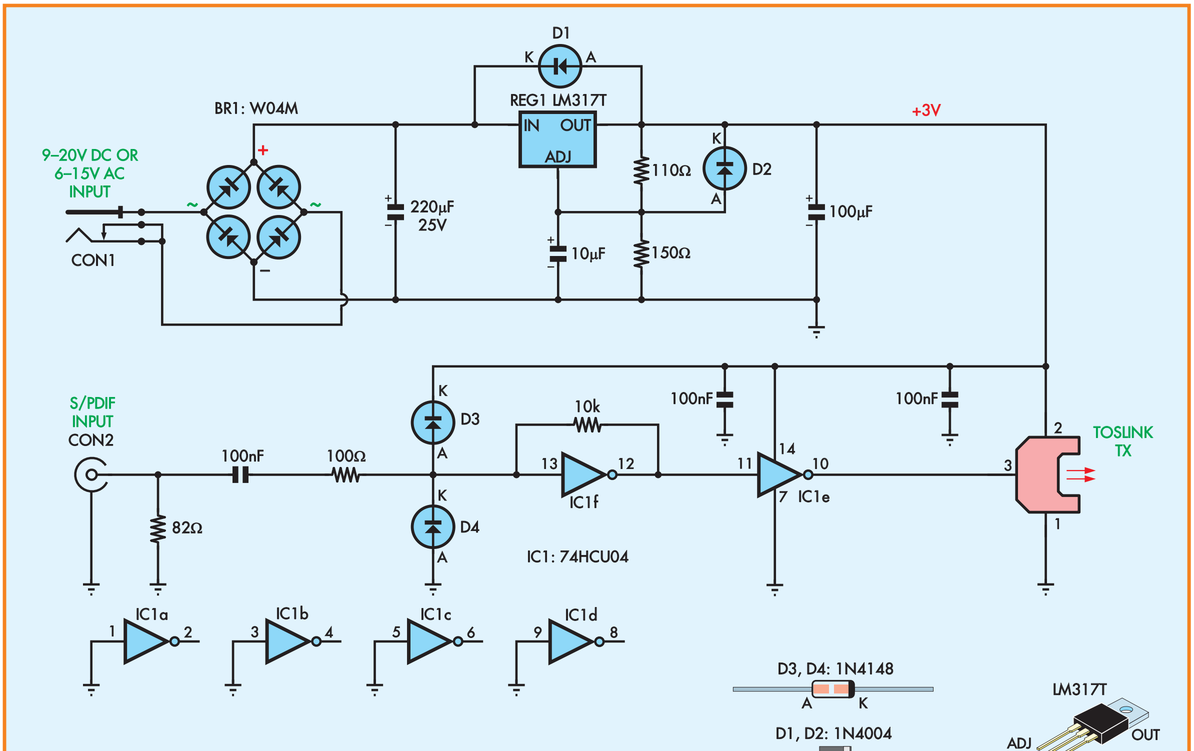
Another useful application is for sending an optical audio signal from one side of a room to the other or even into another room. While wall plates are available for sending TOSLINK over Cat5 network cable, they are expensive and require a power supply at each end, which will constantly draw power unless an additional wall switch is installed to turn them on and off.

With a pair of these converters, you can first convert the TOSLINK signal to an S/PDIF signal and then feed it into a wall plate via a 75Ω RCA-to-RCA lead (composite video leads are suitable). The signal is then carried over standard 75Ω coaxial cable (eg, RG-6/U or RG-59/U) to the other wall plate. From there, it's then fed via another RCA-to-RCA lead into the second converter and converted back to optical (TOSLINK) format.

The power supply at each end (typically a plugpack) can easily be switched off at the wall, along with the sending and receiving equipment, to save power when it is not in use.

Performance

We tested both converters with Dolby Digital, DTS and linear PCM audio data. The PCM tests included both



S/PDIF TO TOSLINK CONVERTER

Fig.1: the *S/PDIF to TOSLINK Converter* uses high-gain inverting amplifier stage IC1f and inverting stage IC1e to square up and buffer the input signal. IC1e then drives the TOSLINK transmitter. .

48kHz 24-bit stereo and 96kHz 24-bit stereo audio streams.

Both units were able to correctly handle all of these streams with one exception: if the TOSLINK to S/PDIF converter is built with a receiver module rated to handle 8Mbps (such as the Altronics Z1602), then it may not work with 96kHz 24-bit linear PCM.

This type of audio has a bit rate of 6.144Mbps (96,000 × 2 × 32) so it seems that the nominal 8Mbps unit should be able to handle it. However, that specification is listed as a maximum rather than typical rating, and the measurement conditions involve a cable only 1m long and a stated duty cycle of 50%. In reality, NRZI-encoded data, if considered as being at fixed frequency, has a variable duty cycle.

We also tested a 16Mbps receiver (Jaycar ZL3003) and this handled the 96kHz PCM stream correctly. However, unless you are using a DVD-audio player or computer sound card with 96kHz capability, the highest sample rate you are likely to transmit is 48kHz (with a bit rate of 3.072MHz). In this case, either receiver unit is suitable. The data in Dolby Digital and DTS streams is compressed, so their bit rates are lower again.

Power supply

Either an AC or DC plugpack can be used to power these converters. The acceptable voltage range is 6V to 15V AC for AC plugpacks and 9V to 20V DC for DC plugpacks. The current consumption is below 20mA in each case.

Power is applied to each converter board via a 2.5mm ID DC power socket, which suits many but not all plugpacks. In some cases, an adaptor plug may be required or you will have to change the DC connector on the plugpack to suit the on-board socket.

If you are the type of person who keeps plugpacks from defunct equipment then you will almost certainly have something suitable. Otherwise, buy the cheapest option, which suits the above requirements (eg, Jaycar MP3020) but if it has a fixed plug, check that it's a 2.5mm type.

Circuit details – S/PDIF to TOSLINK

Fig.1 shows the circuit diagram for the *S/PDIF to TOSLINK Converter*. Either AC or DC power is supplied via CON1, a PC-mount DC connector.

If the supply is AC, it is rectified by bridge rectifier BR1 and filtered by a 220µF capacitor to form an unregulated DC supply. If DC is supplied from the plugpack, it charges the 220µF capacitor directly via BR1 and the connector polarity does not matter because only two of the diodes within BR1 will conduct.

Which two diodes actually conduct depends on whether the supply plug is centre positive or negative. Because there are always two diodes in series with the supply, its voltage is reduced by around 1.4V (two diode drops),

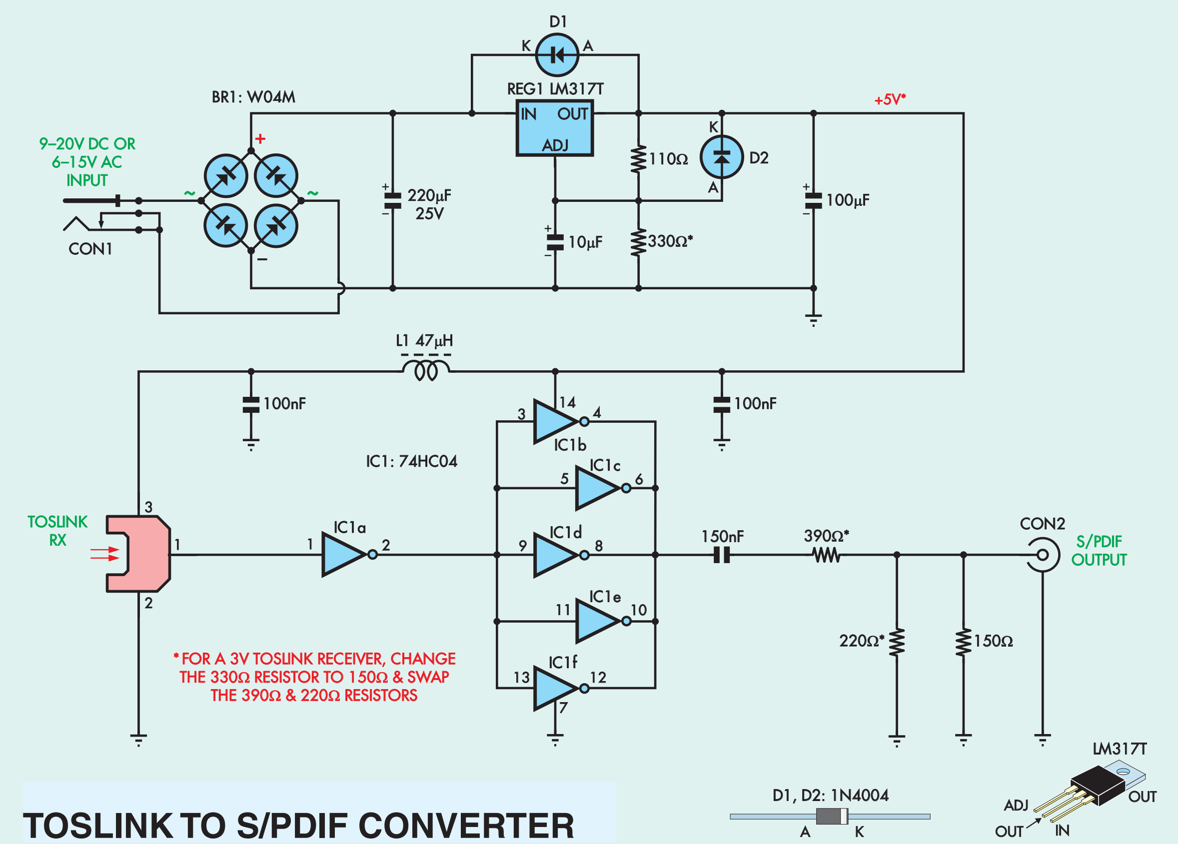


Fig.2: the *TOSLINK to S/PDIF Converter* uses a TOSLINK receiver to drive inverter stage IC1a. Its output is in turn buffered and inverted by IC1b to IC1f, which then drive the output via a 150nF capacitor and a divider stage.

which is more than the typical 0.7V loss with a single reverse polarity protection diode. As the circuit runs at such a low voltage, this doesn't really matter.

The filtered DC supply is regulated to around 3V by adjustable regulator REG1. Its output voltage being set by the ratio of the two resistors on its OUT and ADJ terminals and is (150Ω/110Ω + 1) × 1.25V = 2.95V. In practice, it's slightly higher than this due to the leakage current from REG1's adjust pin.

The 100μF capacitor provides output filtering for REG1, while the 10μF capacitor bypasses the ADJ (adjust) pin, improving supply ripple rejection. Diodes D1 and D2 protect REG1 from the charge stored in those two capacitors should its input be shorted. That is unlikely because of BR1, however they are cheap insurance and make the regulator circuit virtually 'bulletproof'.

Signal conversion

The S/PDIF audio signal enters the board via RCA phono socket CON2. It is a bi-phase encoded digital signal (also known as 'non-return to zero' or NRZI encoding) which, when terminated with 75Ω, has a voltage swing of about 0.5V peak-to-peak. Its frequency depends on the data format and sample rate, but is typically between about 0.9MHz and 6MHz.

IC1f is part of a 74HCU04 unbuffered inverter IC and is configured as a high-gain inverting amplifier. The incoming digital signal is AC-coupled to its input via a 100nF capacitor. The 82Ω and 100Ω resistors together set its input impedance to around 75Ω, matching the source and cable impedance for minimum signal attenuation.

Diodes D3 and D4 protect IC1f should a higher amplitude signal be accidentally connected to CON2 (or if a high-voltage spike gets in for some other reason). IC1f's closed-loop gain is set by the ratio of the 10kΩ and 100Ω resistors, ie, it is around 100. This is enough so that its output swings fully between the supply rails with a 0.5V input signal, while also squaring up the digital signal.

This output is buffered and inverted again by IC1e, so that its polarity is the same as at the input (although with NRZI encoding, polarity doesn't matter). That signal is then sent directly to the TOSLINK transmitter (Tx), which modulates its output LED to transmit the digital signal over optical fibre.

On the buffers

Note that we have used a 74HCU04 inverter in this circuit, rather than a 74HC04 (which is easier to get). The reason for this is that the 74HC04 has a much higher open-loop gain and larger phase shift (ie, signal delay) between its input and its output. That's

Using the Altronics 3V TOSLINK receiver

The parts layout shown in Fig.4 for the TOSLINK to S/PDIF Converter suits a 5V TOSLINK receiver (eg, Jaycar ZL3003). Alternatively, if you are using a 3V TOSLINK receiver (eg, Altronics Z1602), be sure to change the indicated resistor values.

Both the Jaycar and Altronics TOSLINK transmitters (Cat. ZL3000 and Z1601 respectively) operate from 3V, so no such changes are required on the S/PDIF to TOSLINK Converter board (Fig.3).

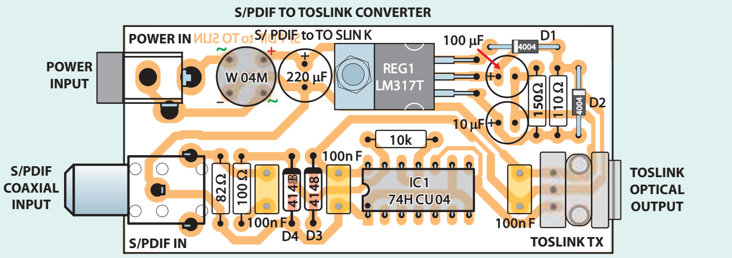


Fig.3: follow this parts layout diagram to build the *S/PDIF to TOSLINK Converter* circuit. It converts coaxial SPDIF signals to optical format.

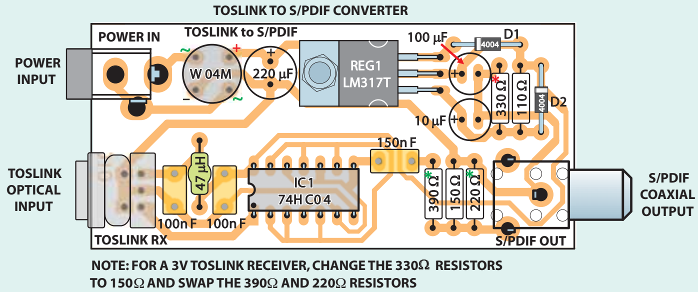


Fig.4: this is the layout for the *TOSLINK to S/PDIF Converter* circuit. It converts optical (TOSLINK) signals to coaxial format. Note that you have to swap some resistor values if you are using a 3V TOSLINK receiver.

because each section of the 74HC04 is actually three CMOS inverters in series. This is done to reduce the input capacitance and improve the output drive strength, which are desirable properties in a digital circuit.

However, these factors combine to make it unstable in this type of configuration, and even a small amount of noise picked up at its input can cause the output to oscillate at a very high frequency (tens of MHz). This increases the circuit's power consumption when there is no input signal and also causes it to emit more electromagnetic interference (EMI).

The 74HCU04 IC is a little different, as each of its sections is just a single CMOS inverter. These devices are primarily intended for use in crystal oscillator circuits, but they also work well for amplifying low-level digital signals, as in this case. So, while a 74HC04 may work in this circuit, it is undesirable to make the substitution for the reasons stated earlier.

Circuit details – TOSLINK to S/PDIF converter

Now let's take a look at the *TOSLINK to S/PDIF Converter* – see Fig.2.

The power supply is identical to that used in Fig.1 except that its output voltage must be tailored to suit the particular TOSLINK receiver (Rx) used. For 5V receivers, such as the Jaycar ZL3000, 110Ω and 330Ω resistors are used at its OUT and ADJ terminals since (330Ω/110Ω + 1) × 1.25V = 5V. For 3V receivers, such as the Altronics Z1602, the same resistors are used as for the other converter (ie, the 330Ω resistor is changed to 150Ω).

Inductor L1 and its associated 100nF capacitor form an *LC* low-pass filter. This isolates the TOSLINK receiver's supply from the main supply so that switching noise cannot be coupled back into it and upset its internal high-gain amplifier. The internal amp is fed from a phototransistor which picks up the bi-phase signal from the optic fibre, converting it to a digital electrical signal at its pin 1 output.

This signal is now buffered and inverted by IC1a (part of a 74HC04 hex inverter IC) and then again by the remaining five inverter stages. These are hooked up in parallel to provide enough current to drive a 75Ω load.

Output

The signal at the inverter outputs is then AC-coupled via a 150nF capacitor, so that it is centred about ground potential, and its amplitude reduced by a resistive divider made from three resistors. This divider also provides the correct output impedance of

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	10kΩ	brown black orange brown	brown black black red brown
❏	1	390Ω	orange white brown brown	orange white black black brown
❏	1	330Ω	orange orange brown brown	orange orange black black brown
❏	1	220Ω	red red brown brown	red red black black brown
❏	1	150Ω	brown green brown brown	brown green black black brown
❏	1	110Ω	brown brown brown brown	brown brown black black brown
❏	1	100Ω	brown black brown brown	brown black black black brown
❏	1	82Ω	grey red black brown	grey red black gold brown

around 75Ω (actually, 72.5Ω assuming the resistors are accurate).

Because the circuit can operate from either a 3V or 5V supply rail (depending on the TOSLINK receiver used), the divider ratio must be configured to provide the correct output signal level. The resistors in Fig.2 are shown configured for a 5V supply rail.

The 220Ω and 150Ω resistors in parallel are equivalent to an 89Ω resistor, so the 5V peak-to-peak output from the inverters is translated to 5 × 89/(390 + 89) = 0.929V peak-to-peak. This is close enough to the 1V wanted. Since the source impedance is 75Ω and the signal is terminated by 75Ω at the other end, the receiver can therefore expect to receive a signal which is a little under 0.5V peak-to-peak.

For a 3V supply rail, we swap the 220Ω and 390Ω resistors. The two resistors in parallel then form a 141Ω equivalent resistor and the formula becomes 3 × 114/(220 + 114) = 1.024V peak-to-peak, again within the acceptable range.

Parts List – TOSLINK – S/PDIF audio converters

S/PDIF to TOSLINK Converter

- *1 PC board, code 868, size 74mm × 34.5mm
- 1 black switched PC-mount RCA phono socket (Jaycar PS0279, Altronics P0145A)
- 1 TOSLINK transmitter (Jaycar ZL3000, Altronics Z1601)
- 1 2.5mm ID PC-mount DC socket
- 1 M3 × 6mm machine screw
- 1 M3 shakeproof washer
- 1 M3 nut
- 1 75mm length of 30mm diameter heatshrink tubing

Semiconductors
- 1 74HCU04 hex unbuffered inverter IC (IC1)
- 1 LM317T adjustable linear regulator (REG1)
- 1 W04(M) bridge rectifier (BR1)
- 2 1N4004 diodes (D1, D2)
- 2 1N4148 diodes (D3, D4)

Capacitors
- 1 220µF 25V radial electrolytic
- 1 100µF 16V radial electrolytic
- 1 10µF 16V radial electrolytic
- 3 100nF MKT

Resistors
- 1 10kΩ
- 1 150Ω
- 1 110Ω
- 1 100Ω
- 1 82Ω

Alternative parts: W04(M) may be substituted with W02(M), W06(M), W08(M) or W10(M)

TOSLINK to S/PDIF Converter

- *1 PC board, code 869, size 74mm × 34.5mm
- 1 TOSLINK receiver (Jaycar ZL3003, Altronics Z1602)
- 1 black switched PC-mount RCA socket (Jaycar PS0279, Altronics P0145A)
- 1 2.5mm ID PC-mount DC socket
- 1 47µH axial RF inductor (L1)
- 1 M3 × 6mm machine screw
- 1 M3 shakeproof washer
- 1 M3 nut
- 1 75mm length of 30mm diameter heatshrink tubing

Semiconductors
- 1 74HC04 hex inverter IC (IC1)
- 1 LM317T adjustable linear regulator (REG1)
- 1 W04(M) bridge rectifier (BR1)
- 2 1N4004 diodes (D1, D2)

Capacitors
- 1 220µF 25V radial electrolytic
- 1 100µF 16V radial electrolytic
- 1 10µF 16V radial electrolytic
- 1 150nF MKT
- 2 100nF MKT

Resistors
- 1 390Ω
- 1 330Ω (for 5V TOSLINK receiver)
- 1 220Ω
- 1 150Ω (2 for 3V TOSLINK receiver)
- 1 110Ω

Alternative parts: W04(M) may be substituted with W02(M), W06(M), W08(M) or W10(M); 47µH axial RF inductor may be substituted with 68µH or 100µH

*Both printed circuit boards available from the *EPE PCB Service*

Construction

The two PC boards are the same shape and size and the construction procedure is similar. The *S/PDIF to TOSLINK Converter* board is coded 868, while the *TOSLINK to S/PDIF Converter* board is coded 869. Both measure 74mm × 34.5mm. Both these printed circuit boards are available from the *EPE PCB Service*.

Fig.3 shows the component layout for the *S/PDIF to TOSLINK Converter*, while Fig.4 has the parts layout for the *TOSLINK to S/PDIF Converter*.

Whichever board you choose to build, start by checking the copper tracks to ensure that there are no breaks or short circuits. Also check that the holes are drilled to the correct size and that the components fit, especially the three connectors, the regulator and the bridge rectifier.

That done, fit the resistors. Check each with a multimeter set to ohms before installation and **remember to change three resistors on the *TOSLINK to S/PDIF Converter* board if you are using a 3V TOSLINK receiver – see Fig.2 and Fig.4.**

The discrete diodes can go in next. Be sure to install them with the correct polarity, and don't get the 1N4004 and 1N4148 diodes mixed up on the *S/PDIF to TOSLINK Converter* board.

If you are building the *TOSLINK to S/PDIF Converter*, install the 47µH axial inductor (L1) next. It looks similar to a resistor, but is usually 'fatter' and may also be a different colour.

Now mount the 74HCU04/74HC04 IC. Check that it is correctly orientated and be sure to push it all the way down on to the PC board fully before soldering all 14 pins. You can, if you wish, use IC sockets here.

Regulator and bridge rectifier

The LM317T regulator is next on the list. To install it, first bend its leads down at right-angles 6mm from its body, then fit it to the PC board and secure its metal tab using an M3 × 10mm machine screw, nut and shakeproof washer. Do the nut up firmly, then solder and trim the three leads.

Do not solder the regulator's leads before securing its metal tab to the board. If you do, you could crack the

Using a single plugpack with multiple converters

IF YOU REQUIRE multiple converters in one location, they can be powered from a single plugpack using a 'Y-cable'. However, you have to be careful that this arrangement does not introduce any 'earth loops'. It's just a matter of ensuring that no two converters share a plugpack if one has a coaxial cable connected to a power amplifier while the other has a coaxial cable connected to a signal source (eg, DVD player).

The power splitter (Y) cable shown here was made using two 2.5mm ID DC plugs, one in-line 2.5mm ID DC socket and approximately 1m of twin core flex, which can be salvaged from a dead plugpack (including one of the DC connectors).

Begin by cutting the cable into three sections of roughly equal length. Split the wires apart at each end and strip the insulation back. You will need to split the wires by a few centimetres to allow enough length to slip heatshrink over the leads while leaving the exposed ends far enough away so that the heatshrink doesn't shrink prematurely when soldering.

Next, unscrew the plastic shell from each connector and pass one of the cables through it. Slip a 20mm length of 2.5mm diameter heatshrink over one lead and solder that wire to the smaller of the two tabs on the connector. That done, slide the heatshrink tubing over the soldered joint and the metal tab and shrink it down.

Next, solder the other wire to the larger tab and crimp the metal clamp over the cable to hold it in place. Make sure the two conductors cannot contact each other, then screw the plastic cover back into place.

Once all three wires have been soldered to the connectors, slide a 40mm length of 5mm to 6mm diameter heatshrink on to the line socket cable and two 20mm lengths of 3mm-diameter heatshrink over the individual leads. Twist all three positive wires together (with the line socket cable facing the opposite direction to the other two) and apply solder to the joint – an alligator clip stand will help hold the wires steady.

Check that all three centre pins are electrically connected and then shrink the smaller piece of heatshrink tubing over the solder joint. Now repeat this procedure for the three negative wires and then shrink the larger diameter insulation over both joints and the cable is complete.

copper tracks of the PC board as the nut is tightened down.

Now install the bridge W04M rectifier. Make sure that the '+' marking on the top of the device lines up with the '+' on the layout diagram and check that it is correctly seated on the PC board before soldering its pins.

Follow this by fitting the three MKT capacitors (note the location of the 150nF capacitor on the *TOSLINK to S/PDIF Converter*). After that, you can mount the electrolytic capacitors, being careful to check their orientation.

The three connectors can now be fitted. Ensure that they are pushed down fully on to the PC board and are parallel with the edge before soldering their pins. The plastic posts on the RCA phono socket should go most of the way through the holes on the board (you may have to push it down fairly hard to get it to fit). Similarly, the DC socket may need to be pressed down firmly, as it can be a tight fit.

Use a generous amount of solder for the larger pins on both the DC and RCA sockets to ensure they are well-anchored.

The TOSLINK transmitter on the *S/PDIF to TOSLINK Converter* board is initially held in place with two plastic posts which snap into the appropriate holes. It is then just a matter of soldering the three pins. By contrast, the TOSLINK receiver on the *TOSLINK to S/PDIF Converter* is held in place by two large metal pins. They should be soldered first, after which the three signal pins can be soldered.

Testing and heatshrinking

That completes the board assembly, which should now be carefully checked for errors. That done, apply power and test the adaptor before encapsulating it in heatshrink tubing. During this test, take care to ensure that the parts cannot short against any metal objects, especially on the underside of the PC board.

It is also a good idea to check the underside of the PC board to make sure that there are no long protruding pins which may later pierce through the heatshrink insulation. If there are, cut them off short with side-cutters.

Once you have confirmed that the converter is functioning correctly, cut the heatshrink tubing to a length of 75mm, slide it over the unit so that it projects evenly over both ends and apply some gentle heat (eg, from a hair drier). Be careful not to bump the heatshrink out of position while doing this and be careful not to overheat it if using a hot-air gun.

That's it! If you need additional converters, just build some more. They should each take no more than about 30 minutes to assemble. ***EPE***

Something old, something new

TechnoTalk

Mark Nelson

Valves are back (if they ever went away) but this time it's different. Recycling used electronics devices is becoming more profitable, while telly viewers are under attack from new 4G phones. Mark deals out the details.

PHYSICAL barriers are blocking scientists from achieving more efficient electronics, argues Prof Hong Koo Kim of the University of Pittsburgh in the States. Clever as transistors are, he believes, the demand for faster, more energy-efficient technologies means that silicon electronics are falling short, so his research team is turning back to hollow-state electronics (valves or vacuum tubes) as the medium for electron transport.

No joke

The prof is serious. 'We worked toward solving that road block by investigating transistors and their predecessor – the vacuum tube,' he states. The upper limit of transistor speed, says Kim, is determined by the 'electron transit time', the time it takes an electron to travel from one device to the other.

Electrons travelling inside a semiconductor device frequently experience collisions or scattering in the solid-state medium. Kim likens this to driving a vehicle on a bumpy road – cars cannot speed up very much. 'The best way to avoid this scattering – or traffic jam – would be to use no medium at all, like vacuum or the air in a nanometre scale space,' says Kim. 'Think of it as an airplane in the sky using an unobstructed journey to its destination.'

Coulombic repulsion is the thing

His team decided to redesign the structure of the vacuum electronic device altogether. They discovered that electrons trapped inside a semiconductor at the interface with an oxide or metal layer can be extracted easily out into the air. The electrons at the interface form a sheet of charges, called 'two-dimensional electron gas'. Kim found that the coulombic repulsion – the interaction between electrically charged particles – in the electron layer, enables the easy emission of electrons out of silicon. The team extracted electrons from the silicon structure efficiently by applying a negligible amount of voltage and then placed them in the air, allowing them to travel without any collisions or scattering.

His conclusion is clear enough. 'The emission of this electron system into vacuum channels could enable a new class of low-power, high-speed transistors, and it's also compatible with current silicon electronics'. He argues, 'With this finding, there is the potential for the vacuum transistor concept to come back, but in a fundamentally different and improved way.'

Recycling resurgence

Perhaps it's a sign of tougher times, but firms are paying better money for mobile phone handsets for recycling. Whereas, £20 was the average value of a handset for recycling five years ago, the equivalent value is now £105. So says Andrew Beckett in trade journal *Mobile News*, adding that this subdivision of the mobile phone industry has become a billion-pound business in its own right. Beckett is co-founder and commercial director of consumer website **CompareMyMobile.com** (not to be confused under any circumstances with CompareMyMobile.co.uk!). With the huge growth of the market for tablet computers, he thinks these will likely become the next big thing for recycling.

EPE readers don't need to be convinced of the merits of recycling or 'ratting' other people's cast-off electronics of course, but even they may be unaware there are around 40 million gaming consoles, PCs, digital cameras and other electronic gadgets in people's houses will need recycling. On average, people upgrade their handsets every 18 to 24 months, but just sit on their old handset, never thinking they could sell it online.

The only safe way to get the most cash for phones, and also have the data deleted off your phone properly, so that stalkers don't get your pictures and Facebook logins, is to use a reputable mobile phone recycling service. The website lists all the options and also lets you in on some industry secrets.

Whose problem is it anyway?

If you live in one of the 2.3 million British households which have digital television viewing, you could well be plagued by interference from the new fourth generation (4G) mobile radio networks when they come on stream next year. About one home in ten will be affected, assuming that you watch the Freeview channels, and the fur is flying over who should pay to sort out the setback.

There seems to be little dispute that 4G mobile signals will cause interference to Freeview viewers living within 2km of a 4G base station, also that installing a replacement TV antenna and filter to eliminate the interference will cost between £156 and £224.

So who will pay for this outlay? Freeview, which currently provides free digital TV to over 20 million homes in the UK, says that 'consumers should not have to pick up the bill and that the mobile operators should be responsible for the full costs associated with protecting viewers' TV services'.

'Freeview homes should not be subject to further inconvenience and additional cost to make way for mobile broadband. By the time 4G services roll out, over 90 per cent of the UK will have Freeview, either on a main or secondary set.'

Vouchers

The most recent word from the government came in July, when communications minister, Ed Vaizey, stated in a letter to communications regulator OFCOM: 'The Government is keen to mitigate the effects of interference, so that no television viewer loses access to television services.' Help will be available to affected homes, he continued, with filters to prevent interference problems, provided free of charge by the government help scheme.

Vouchers will be provided to eligible households to pay for the installation of a filter to a rooftop aerial, if required. Where filters cannot improve reception, Mr Vaizey said assistance would be provided to switch to free-to-view satellite or to cable TV.

So far, so good, but do the proposals go far enough? Not according to TV transmitter Arqiva, which stated, 'We remain very concerned that disruptions to secondary set users and households that depend on set-top or loft-mounted aerials for their reception have been completely ignored'.

BUILD IT NOW IN TIME FOR YOUR CHRISTMAS EXTRAVAGANZA!

DIGITAL LIGHTING CONTROLLER

Part 1 – by Nicholas Vinen and Jim Rowe

Want one up on your neighbours? Instead of a static Christmas lights display (*so* passé!) now you can have the ultimate in Christmas extravaganzas. This amazing controller will bring your Christmas lights to life, making them flash, dim up and down, you name it, all in time with your favourite Christmas music. It's easy to build, easy to connect and, best of all, easy to program!

OK, we have to admit it. We first had this idea after watching Chevy Chase's *Christmas Vacation*. Then it was given further impetus by a YouTube clip we saw a couple of years ago. It's taken a while to put the idea into practice!

You've probably seen the clip we're talking about. Just one version of it has had nearly seven million hits! But if you haven't and/or if you'd like to see the inspiration – and get some idea of what this will do for you, check out **www.youtube.com/watch?v=rmgf60CI_ks** (or simply enter 'Christmas Lights' on YouTube).

Actually, we lie: we're pretty sure that controller only had about 12 to 16 channels. Ours has up to 32, so you'll be able to put that to shame.

You'll be amazed!

Just imagine the neighbours – they'll be as amazed as everyone else who stops to admire your handywork this festive season.

There are certainly some amazing displays this time of year. But for the most part, they're static. They don't DO anything except look pretty. With this controller, yours can look pretty AND look spectacular at the same time.

We know that quite a number of readers have used the *DSP Musicolour Lightshow* (*EPE*, May-August 2010) to control their Christmas lights, flashing them in time with music. That's fine, of course, if all you want is flashing lights.

Like the *Musicolour*, this unit has multiple high-current triac outputs capable of phase-based brightness control. But that's where the similarities end. With this new controller (or more properly called a sequencer)

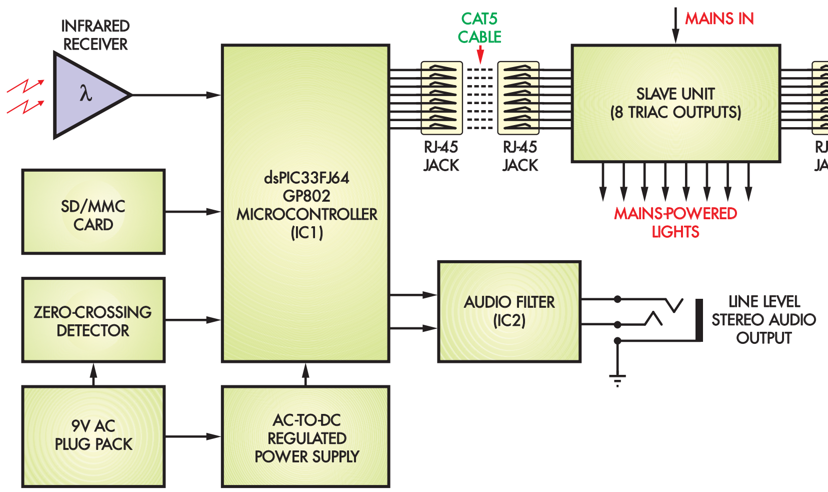


Fig.1: the block diagram showing how both master and slave units operate. The master unit plays the music and sends commands to the slaves, which in turn control the lights. An infrared remote can be used to control the whole lot.

you can program in specific lighting patterns and movements, similar to the YouTube clip mentioned earlier.

We decided that for this application, rather than attempt to synchronise the light show with music being played from another source, it would be best to have the *Controller* itself play the music AND sequence the lights. This makes for a self-contained project which will always keep the light sequence strictly in time with the music.

Hardware

The hardware is split into two sections. One is a small plastic box containing the Master unit, while a larger instrument case houses the Slave unit. Between one and four slave units, each of which controls up to eight channels, can be connected to the master.

The master unit, which is controlled via a handheld remote, plays the music and a sequencer file (which you set up) from an MMC (MultiMedia Card), SD (Secure Digital) card or SDHC (high capacity) card. It sends serial commands to the slaves via a Cat5/6 cable, with up to 30m between the units.

Splitting the project into two parts has two advantages. First, only the slave units contain mains wiring, making it easier to build them safely. Second, you can build the number of outputs you need. One slave with eight channels will drive a small light show, while four slaves, totalling a whopping 32 channels, will create a lighting spectacular worthy of a Broadway hit!

Each slave has eight mains output sockets, but you can use as many or as few of these as required.

While each of the eight slave channels can drive lights up to 1200W at 230V AC (5A), the total amount of power allowed per slave unit is 2300W, limited by the 10A input socket and fuse. The power figures are halved for 115V AC mains.

The master controller fits into the smaller box on top, while each 8-channel slave unit requires the larger case below. Up to four slaves can be connected.

Features

Audio THD+N	0.06%
Audio signal-to-noise ratio	65dB
Audio sample rates (kHz)	11.025, 12.0, 22.05, 24.0, 32.0, 44.1, 48.0
Audio file formats	WAV format, 16-bit PCM, mono or stereo
Music capacity	At least 4GB (ie, more than six hours at CD quality)
Playback order	By directory order, alphabetically or random (shuffle)
Number of light 'channels'	32 (max. 4 slaves = 32 channels)
Light power per channel	25-1200W (230V AC) or 12-600W (115V AC)
Total light power (four slaves)	9200W (230V AC) or 4600W (115V AC)
Extra features	Remote control, filament preheat, volume control
Infrared formats supported	Philips RC5 12-bit, NEC 16-bit

Since we have designed this project for use anywhere in the known universe, mains supply frequencies of 50Hz and 60Hz are supported.

Because the slave power limit is 2300W, if you are using all eight channels with identical lights, the maximum power per channel would be 287W (1.25A).

We don't believe that will normally be a problem because (a) most Christmas tree 'bud' light strings are only 10W to 50W or so, and (b) even PAR38 coloured floodlights are usually only 100W.

The 1200W per channel figure is only possible if some channels are left unused or have lighter loads.

If you wanted to run four slave units giving up to 32 channels, you could do so by spreading them over separate same-phase mains circuits, each of which is normally limited to 15A.

That does NOT mean running four slaves from the one powerboard or double adaptors! (Don't laugh – we've seen much worse.)

While a personal computer is used to initially set up the music files and sequences, no PC is required for playing the music or controlling the light sequence. This results in a simplified set-up with increased safety and less power consumption.

Music output

Finally, the master unit also has a line-level audio output to drive virtually any amplifier, perhaps with outdoor speakers, so everyone can enjoy the music and lightshow.

Perhaps your neighbours may not be too happy for you to set up loudspeakers playing Christmas music continuously along with your light show (bah, humbug!).

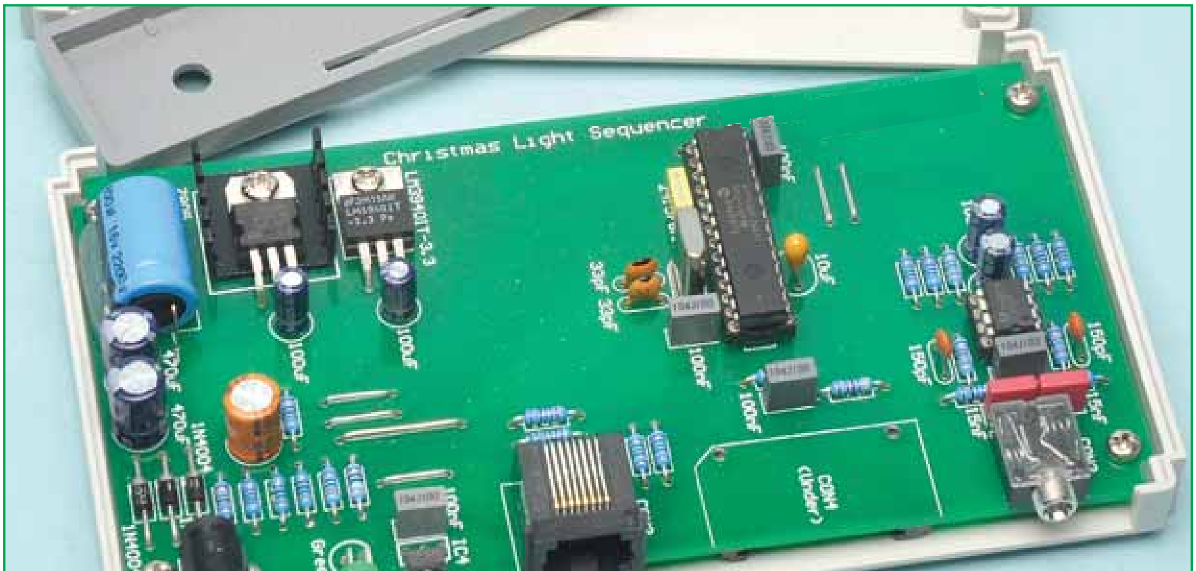
As suggested by a reader, one clever solution is to wire up a small FM transmitter (built from a kit or purchased as a retail device) so that people can tune in and listen in their cars or even their mobile phones while watching the show.

A sign out the front could say 'to listen in, tune your car radio to 88.X MHz' (or something similar). Just make sure you don't pick a frequency occupied by an FM radio station in your area!

Apart from Christmas lights?

This project isn't just limited to a Christmas light application.

It can be used any time that you want lights to be controlled synchronously with audio. For example, it could be used in a museum exhibit, where pressing a button activates narration explaining the exhibit while the appropriate sections are lit up in turn.



Here's the main prototype sequencer unit with DC power input, infrared receiver, data output socket, SD/SDHC/MMC card reader (under PC board) and at right, the 3.5mm audio output socket. Full construction details will appear next month.

Or it could be used as part of an art project, where music and/or narration/music/sound effects are accompanied by different sections being illuminated or devices powered up and down.

Another suggestion is to provide 'mood lighting' or even to switch lights on and off over the course of a day when you are away from home, so that it looks like somebody is still there.

Not only will you achieve a much more realistic light pattern than with a switchboard (the usual method), you can also have music playing to make you home look *and* sound *really* occupied!

We've designed the switching so that theoretically other mains devices (eg, small motors) can also be controlled, but of course, if this is done, 'dimming' via phase control must NOT be attempted! It really is intended to be used with resistive loads, eg lights.

How it works

Refer to Fig.1, the block diagram of the *Digital Lighting Controller* system. At the heart of the project is the dsPIC33FJ64GP802 microcontroller from Microchip. It has 64KB of FLASH program memory, 16KB of RAM (random access memory) and will processs up to 40 MIPS (millions of instructions per second).

This IC is responsible for controlling all the functions of the sequencer, including music playback and triac triggering/phase control (see panel).

During a light show, IC1 reads one WAV audio file at a time from the attached MMC/SD/SDHC card and plays it back using its internal digital-to-analogue converter (DAC). The output of the DAC goes through a filter which removes some of the digital noise.

The resulting signal level is around 1V RMS, which is compatible with most amplifier 'aux' (line level) inputs. As well as a hifi/stereo power amplifier, it could be connected to an FM transmitter, headphone amplifier or mixer.

Power for the master module comes from a 9V AC plugpack. There are two reasons why we are using an AC plugpack rather than DC.

First, we need to know when the mains zero-crossing events occur to enable phase control of the lights, for brightness adjustment.

Second, this makes it easy to generate balanced supply rails for the audio filter op amps (IC2). A higher voltage plugpack cannot be used, as that risks exceeding the op amp supply ratings.

The power consumed from the plugpack depends upon how many slave modules are connected and the

Inside one of the slave units. It's basically a mains switching box, under the control of the signals sent by wire from the master sequencer unit. Each of the eight channels has its own triac, with interference suppression and an IEC mains output socket. Front panel LEDs can mimic the mains output.

specifics of the light sequence, but as a rough guide, with one slave module and eight active light channels, it can be expected to be below 250mA/2.5W.

The zero-crossing detection is done by IC1's internal comparator. This compares a reduced amplitude signal from the plugpack AC output to a half-supply rail, resetting a timer each time they cross.

By measuring how long this timer runs, IC1 can determine the mains frequency (50Hz or 60Hz). It needs to know this in order to convert the desired phase angle for each light to a time delay for triac triggering.

Synchronised sequence playback

When the microcontroller (IC1) opens a WAV file for output, it also looks for a file with the same name but a different extension (**.lsq**). This file contains the light sequencing information which you have prepared to demonstrate your lighting brilliance (OK, pun intended!).

It is processed at the same rate as the WAV file is played, so that they remain synchronised. The information it contains indicates when to switch lights on and off, when to change their brightness and what the new brightness settings are – either a fixed percentage of full brightness or indeed fading up/down.

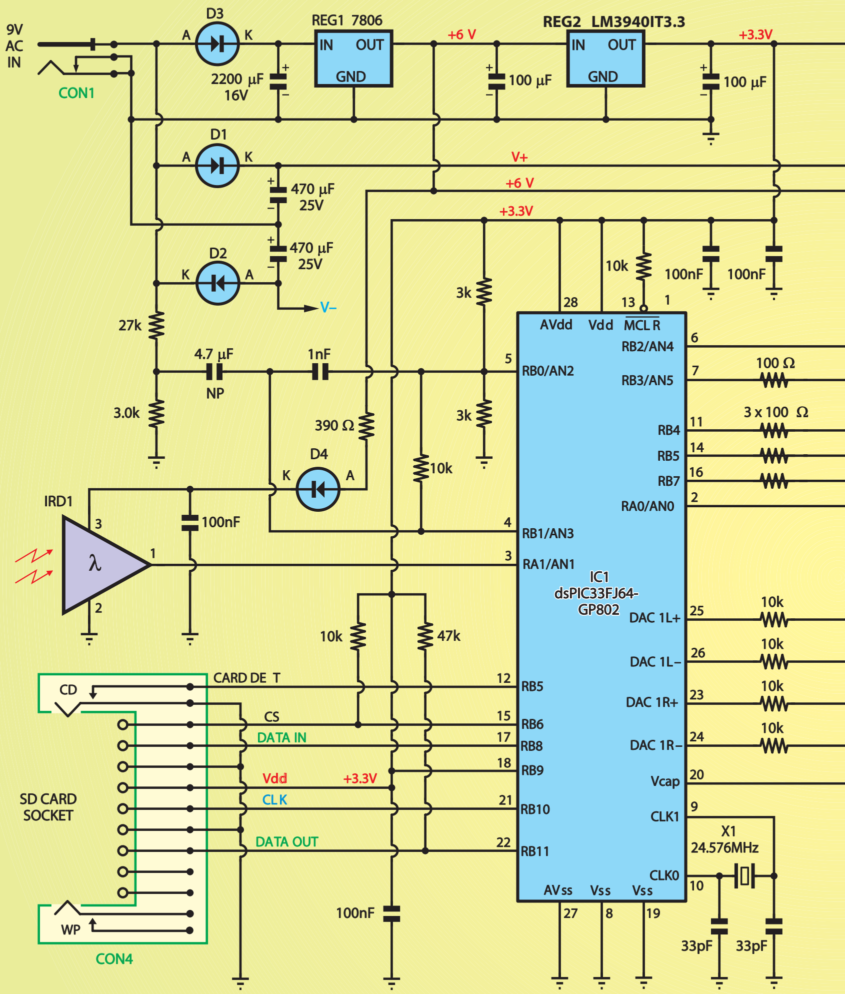
At the appropriate times during each mains half-cycle, IC1 sends serial data out over the RJ45 jack connection. This is carried to each slave module in turn, where the serial data is latched and used to determine which triacs to trigger. As a result, IC1 controls the lights in each slave module as determined by the sequence file.

This sequence file is generated with the Windows software we have developed, which will be available from the *EPE* website next month (at the same time as the article containing the construction details).

We will also provide source code for this software for any users who are interested in porting it to other operating systems like Mac OS X or Linux.

The light sequence can be generated manually, by using the GUI to indicate at which point in the music to change the output light states.

Or, to save time, the control for some light channels can be automatically derived from the music itself over a given time period, with adjustable parameters to determine how it behaves. The result can be used as-is or can be further edited to your satisfaction.



DIGITAL LIGHTING CONTROLLER – MASTER UNIT

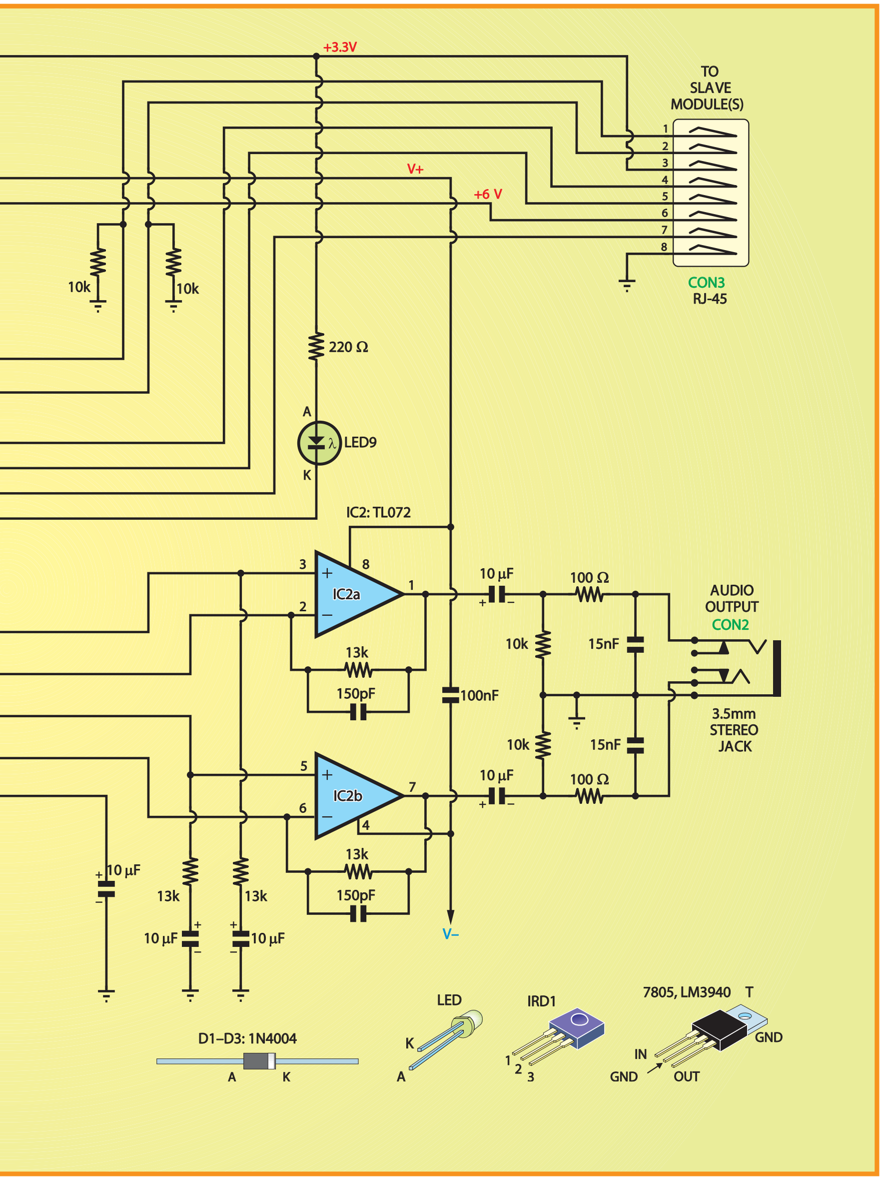
Fig.2: the master unit circuit. At its heart is IC1, a dsPIC running at around 40MHz. IC2 provides gain and filtering for the audio output. Communication with slave units is via CON3, while the music and sequence data are read from the card plugged into CON4.

User interface

The behaviour of the master module is controlled in two ways. First, its default setting are specified in the optional configuration file which is stored on the MMC/SD/SDHC card.

This allows you to determine whether the music files are played back in order or randomly, which file to start with, whether playback starts immediately when power is applied or must be triggered manually and several other options which control the slave unit's behaviour (more on those later).

Further control of the master module is made via the infrared remote control. Available functions include stopping, starting and pausing playback, changing audio tracks, adjusting the volume, playing a specific track, changing the playback order and so on.



The default remote control codes are set up to suit common universal remotes, but they can also be changed using the configuration file.

Cabling

We chose Cat5 cable to connect the slave modules because it is readily available in a variety of lengths, can be made to length, has an appropriate number of conductors (eight) and is weatherproof.

This should enable constructors to easily connect multiple slave modules in different locations, to control a large array of lights.

Because the serial data is buffered by each slave module, this does not limit the total cable length and so 30m cable runs between each unit are possible. In fact longer cable runs may work fine, but 30m is the longest pre-formed cable that is commonly available.

Our test set-up is as follows. We ran a 2m Cat5 patch cable from the master unit to a wall socket which was wired to another wall socket approximately 20m away. Including the vertical runs and other diversions the actual cable run is at least 25m. We then connected a 5m Cat5 patch cable from the other wall socket to the slave unit.

There were no apparent serial data errors over this distance, and the voltage drop on the 6V line was acceptable (a little over 100mV with all eight lights on). Four such cable runs would produce a total of around 400mV to 500mV loss on the 6V line.

In normal circumstances, assuming typical device characteristics, this will leave a high enough voltage at the last slave to reliably trigger its triacs. However, to be safe, it is best to keep the *total* cable run under 50m if possible, especially if wall sockets are involved.

Firmware

While the hardware of both the master and slave modules is fairly straightforward, the software required for IC1 to perform all these tasks is complex. We will not go into great detail in this article; however, the source code will be available for download, along with the HEX file.

During playback, both the WAV and sequence files are read off the MMC/SD/SDHC card synchronously, ie, the software waits for each data packet to arrive. Therefore, the other functions which must be handled simultaneously – DAC output, infrared sensing, zero crossing detection, phase control, etc – must be interrupt driven.

Direct memory access (DMA) is used for the DAC output and SD card access to improve efficiency.

A number of software modules are required to enable the various functions. These include the MMC/SD/SDHC card driver, FAT file system support, WAV file reader, DAC driver, sample rate and clock speed setting functions, infrared decoding, mains phase synchronisation and serial output, audio state playback logic and slave chain length sensing (which uses the internal ADC).

Slave control

The reason that the software calculates the number of attached slaves is that if there are only one or two, it can use the lowest possible serial frequency (72kHz) and only needs to transmit 16 bits (one word) per trigger point.

With three or four slaves, the serial frequency is increased to 96kHz so that

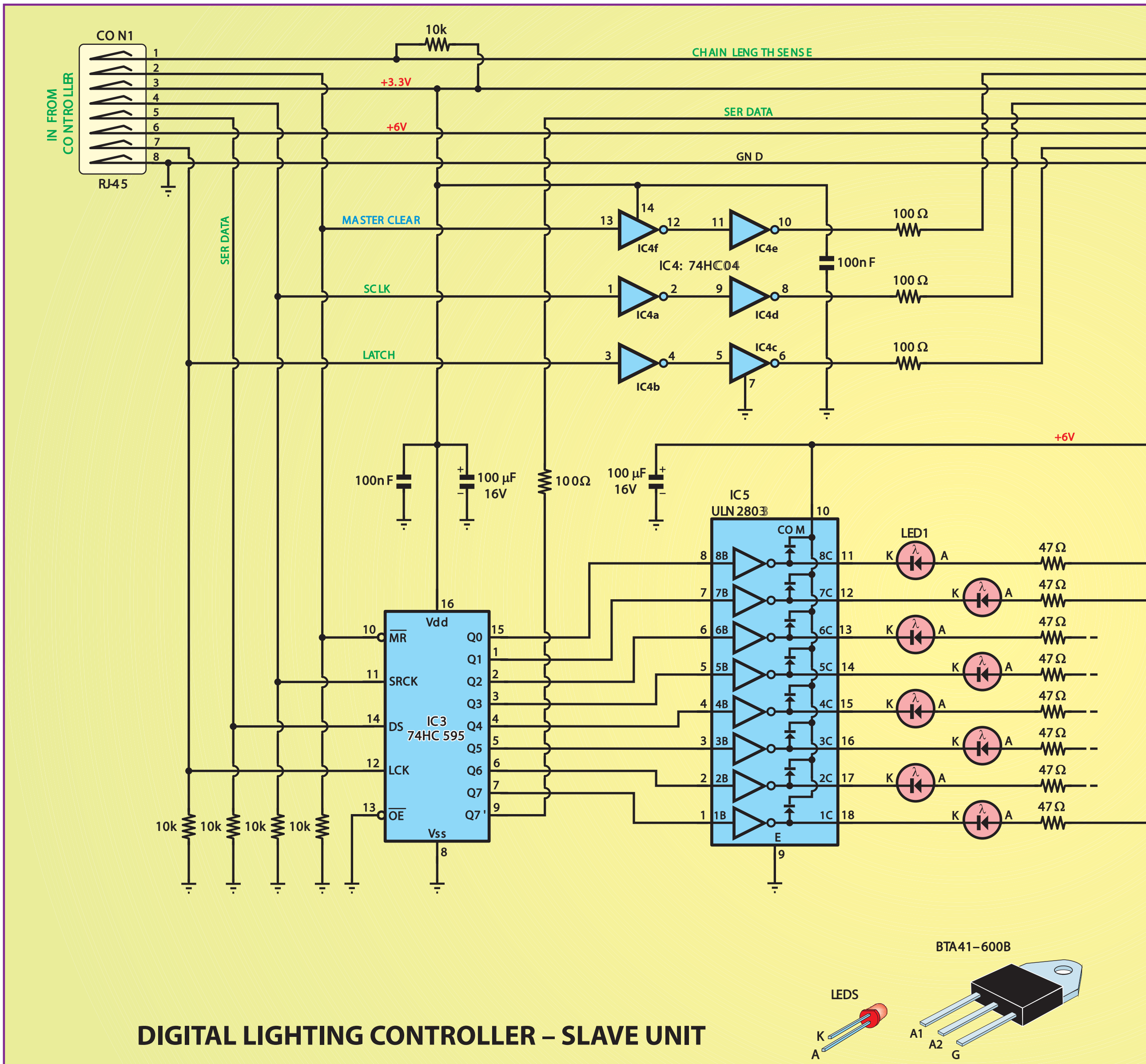


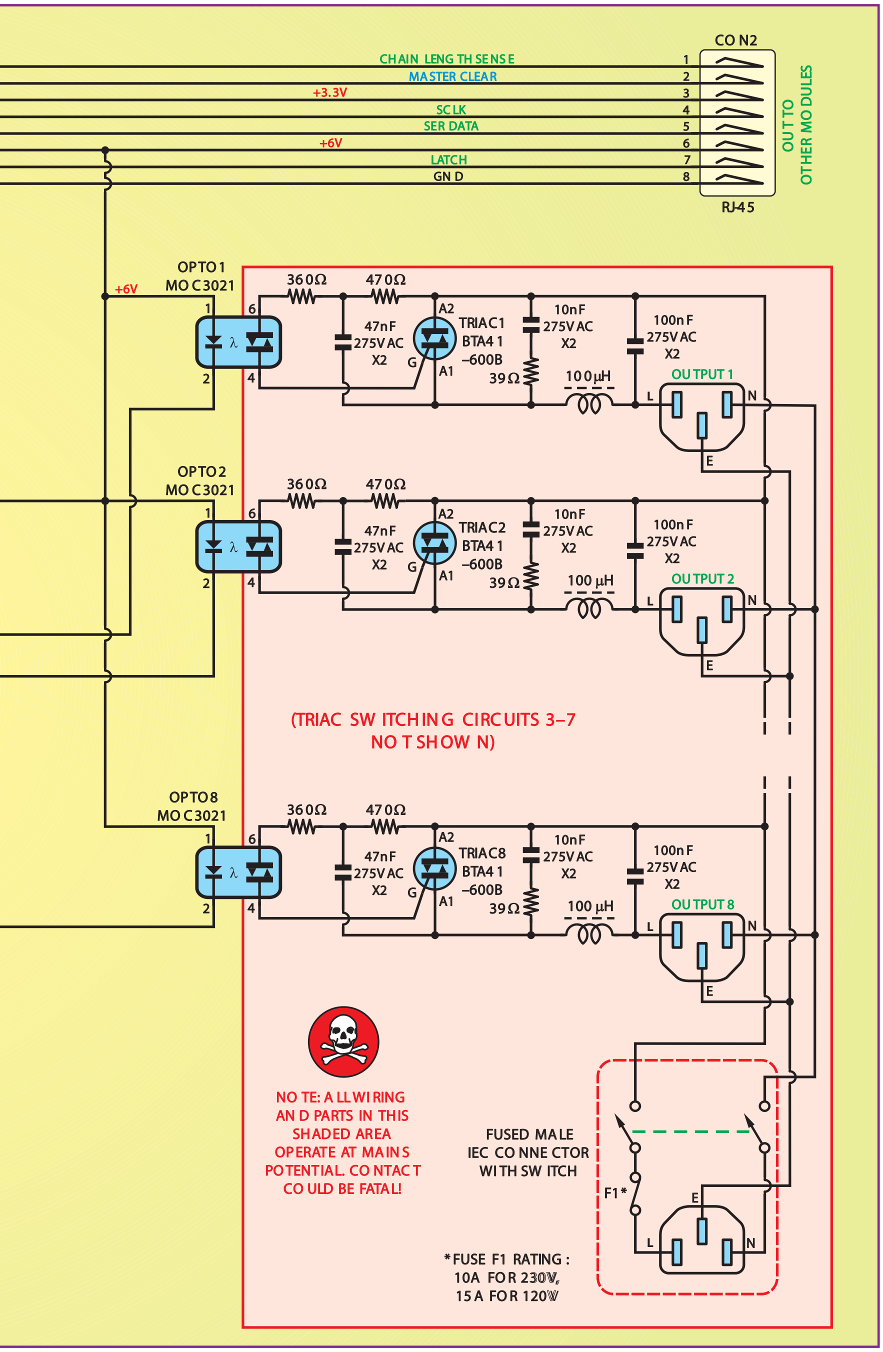
Fig.3: the slave unit uses IC3, a serial-to-parallel latch, to decode the control data. Its outputs drive IC5, an eight Darlington array, which switches current through the optocoupler LEDs (OPTO1 to 8). These control TRIAC1 to 8 and ultimately the lights. The optocouplers and triacs are both equipped with snubber networks to prevent false triggering and an *LC* filter to reduce radiated EMI. IC4 buffers the serial stream to the next slave unit.

32 bits (two words) can be transmitted at each trigger point and will be finished before the next trigger point is reached.

These trigger points are spaced approximately half a millisecond apart and there are up to nineteen trigger points per mains half cycle. In order to allow for smooth brightness control (256 levels), the trigger point used for a given light is 'dithered', ie, it is rapidly toggled back and forth to give intermediate brightness levels.

Because of the filament heat persistence and the persistence of our vision, this rapid brightness variation is not visible. This scheme reduces the required serial rate and makes the microcontroller's job easier, as it can more often send the trigger even for multiple lights together in a single command.

In choosing when to trigger a given triac, the microcontroller also takes account of the fact that the amount of power delivered does not vary linearly with the trigger phase angle. It has a lookup table which allows it to



calculate the percentage of full power that a light will receive for each given trigger period .

This is compared to the desired brightness level and the 'dither error' from the last trigger event in order to calculate the appropriate trigger point.

Because the master module senses mains zero crossings via its AC plugpack supply, by default it assumes that the slave modules are all on the same mains power phase that it is on.

This will be true in the vast majority of cases, as most residences use a single phase for all power outlets. While it is possible to run the controller across multiple phases (indeed, the software can handle this), in the interests of safety and simplicity we do not recommend operation on more than one phase.

Another configuration option which affects slave behaviour is the filament preheat control. Filament preheating means that when lights are off, their power will not drop to zero.

Instead, the filaments are run just below red heat, which means that high repetitive surge currents are largely eliminated when they are being turned on and off frequently.

Two options are provided. One specifies which outputs have lights that require filament preheating and the other determines what percentage of full power is delivered during the off-state.

Circuit description

Refer to Fig.2 for the *Master Unit* circuit diagram. Power from the 9V AC plugpack is delivered via CON1, then rectified separately for two supplies. Diodes D1 and D2 form a full-wave voltage doubler, charging the two 470µF filter capacitors to generate an unregulated split supply of approximately ±13V. This is used to power the op amps.

At the same time, diode D3 half-wave rectifies the AC input, charging a 2200µF filter capacitor for the digital supply. This is regulated to 6V by REG1 and powers the optocouplers in the slave modules.

It is further regulated (by REG2) down to 3.3V for the remaining digital components, including microcontroller IC1 and the digital logic in the slave modules.

The 6V rail voltage is dropped by diode D4, and then further by the 390Ω resistor to provide a 4.5V to 5.5V supply for the infrared receiver (IRD1). This assumes that its current consumption is in the range of 0.5mA to 1.5mA, which is that of the receivers specified in the parts list. The 390Ω resistor and the 100nF capacitor filter its supply, so that any digital switching spikes do not upset its internal amplifier.

Pin 4 and pin 5 are connected to IC1's internal voltage comparator, and this is used for mains zero-crossing detection. The AC input voltage is divided (with a 10:1 ratio) by the 27kΩ and 3kΩ series-connected resistors, resulting in a 0.9V to 1.1V AC sinewave at their junction.

Two 3kΩ resistors hold pin 5 of IC1 at approximately 1.65V (half the 3.3V

Phase-controlled triacs, serial data

In essence, this Digital Lighting Controller can be thought of as a multi-channel light dimmer, all under the control of the dsPIC micro, which in turn is responding to commands written for a particular piece of music stored on the SD card.

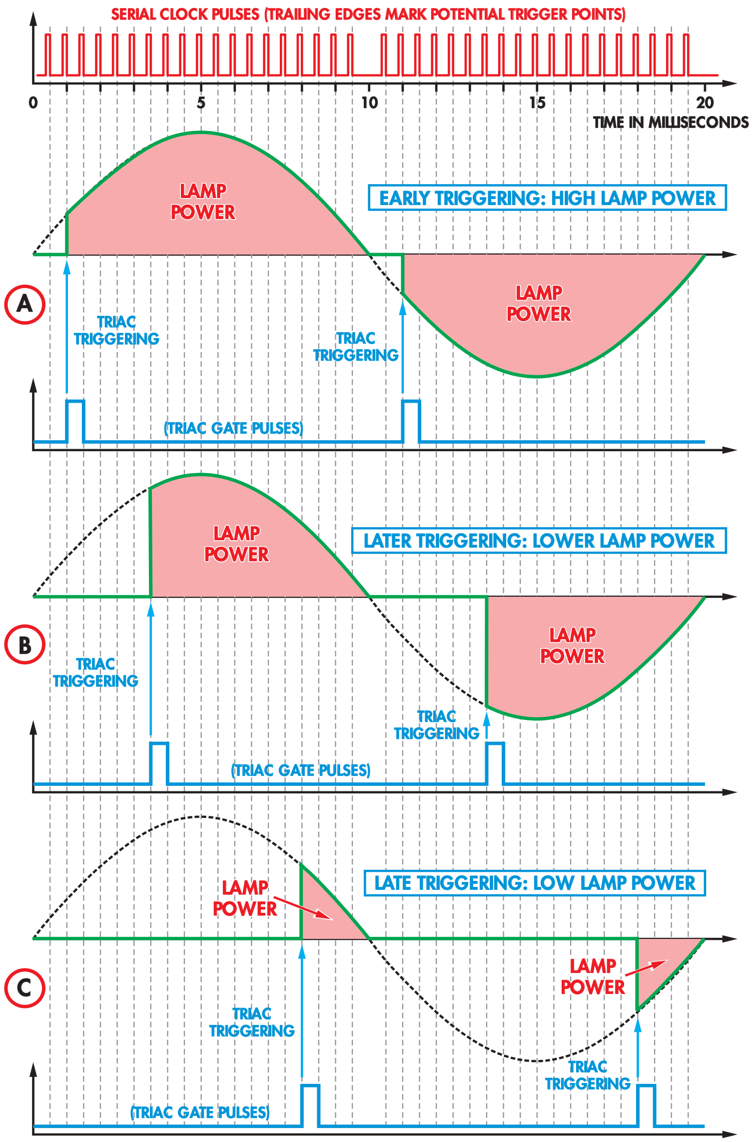
But how do the 'light dimmers' work? Just the same as the light dimmers in your home, they are based on a triac, a four-layer semiconductor device that can switch high voltage AC. When triggered, a triac stays on until the voltage across it drops to zero or reverses.

We vary the power fed to the lamps by triggering the triac earlier or later in each mains half-cycle; the more power the lamp gets, the brighter it will be. This is known as 'phase control' as we are varying the portion of the mains waveform which the lamps receive.

The accompanying diagram illustrates triac triggering on 230V AC mains waveforms, A, B and C. A corresponds to high power since the Triac is on for most of the time. B corresponds to slightly less power, as the riac is triggered later in each AC half cycle. And C corresponds to the lowest power normally used in the Controller, equivalent to the 'filament preheating' referred to elsewhere.

Note that while only three triacs are depicted here, the Controller can drive up to 32 channels (in four slave units).

The serial data stream at the top of the diagram is fed to the serial-to-parallel latch (IC3) and the trailing edge of each data pulse defines the start of a gate signal fed to each triac. Each triac's gate signal (trigger) is on for the time between successive serial data pulses or around 0.5ms. Each triac stays on for the rest of the half-cycle due to its latching action.



supply). The reduced amplitude sinewave is AC coupled to pin 4 of IC1 and also biased to the 1.65V level via a 10kΩ resistor.

For half of each mains wave, the voltage at pin 5 is higher than the voltage at pin 4 and the rest of the time it is lower. IC1's comparator generates a software interrupt every time this changes, allowing it to synchronise a timer to the zero-crossing event. In reality, the voltage at pin 4 does not stay at exactly half supply because current flows back through the 10kΩ biasing resistor, but this does not affect the zero-crossing detection.

Since comparators tend to have an offset voltage between their inputs, the zero-crossing detection is only accurate to within about ±2%. This is taken care of by the software with the insertion of a 'dead zone' around the zero-crossing point. The 1nF capacitor between pin 4 and pin 5 suppresses mains and power supply noise, preventing false comparator triggering.

Infrared receiver IRD1 detects infrared light pulses at the appropriate frequency (around 36kHz). Its logic level output goes straight to IC1's RA1 input (pin 3). This pin is configured to generate an interrupt on a level change and this triggers a decoding sequence whenever infrared pulses are received.

The MMC/SD/SDHC card socket CON4 is wired directly to IC1, which uses an internal SPI peripheral to communicate with the card. The MMC/SD/SDHC card is powered from the regulated 3.3V rail. Pull-up resistors are provided for the card's CS and DATA OUT pins in order to ensure it

Parts List – Digital Lighting Sequencer/Controller

Master module

*1 PC board, coded 870, size 148mm × 80mm
1 front panel label, size 145mm × 20mm
1 2.5mm PC-mount DC socket (CON1)
1 3.5mm PC-mount stereo switched socket (Jaycar PS0133) (CON2)
1 low profile RJ-45 socket (Altronics P1448) (CON3)
1 surface mount MMC/SD/SDHC card socket (Altronics P5720) (CON4)
1 28-pin DIP socket
1 24.576MHz crystal (X1)
1 ABS plastic instrument case, 86mm × 155mm × 30mm (Altronics H0377)
4 nylon washers
4 No.4 × 9mm self-tapping screws
2 6mm M3 machine screws, nuts & shakeproof washers
1 mini TO220 heatsink (Jaycar HH8502l, Altronics H0630)
1 9V AC plugpack 500mA+ (Jaycar MP3027, Altronics M9231)
1 SD, MMC or SDHC card, at least 1GB recommended
15cm tinned copper wire

Semiconductors

1 dsPIC33FJ64GP802 programmed microcontroller (IC1)
1 TL072 dual op amp (IC2)
1 infrared receiver (IRD1) (Jaycar ZD1952, Altronics Z1611/Z1611A)
1 7806T regulator (REG1)
1 LM3940IT-3.3 regulator (REG2)
1 green 5mm LED (LED9)
4 1N4004 diodes (D1-D4)

Capacitors

1 2200µF 16V radial elect.
2 470µF 16V radial elect.
2 100µF 16V radial elect.
4 10µF 16V radial elect.
1 10µF 16V tantalum
1 4.7µF non-polar (NP)
5 100nF MKT
2 15nF MKT
1 1nF MKT
2 150pF ceramic
2 33pF ceramic

www.jaycarelectronics.co.uk
www.altronics.com.au

Resistors

1 47kΩ	1 27kΩ	4 13kΩ	11 10kΩ
3 3kΩ	1 390Ω	1 220Ω	6 100Ω

WARNING!
This is a mains-operated device. Construction should not be attempted unless you have knowledge of and experience in building mains-powered projects.
The slave unit has areas of the PC board where components and tracks are at mains potential. Contact with live wiring could prove fatal.

Software
All software program files will be available from the *EPE* website at **www.epemag.com**.
Although we do not supply pre-programmed microcontrollers, you can purchase the programmed micro featured in this project from: **parts@siliconchip.com.au**

Slave module
(parts for one module [eight channels] only)

*1 PC board, code 871, size 216mm × 157.5mm
1 plastic instrument case, 260mm × 190mm × 80mm (Jaycar HB-5910, Altronics H0482)
1 aluminium rear panel for above case, 2mm thick
1 front panel label, 240mm × 71mm
1 rear panel label, 240mm × 71mm
2 low profile RJ-45 sockets (Altronics P1448)
8 100µH 5A mains-rated inductors (Jaycar LF1270)
4 heavy-duty PC-mount TO-3P heatsinks (Jaycar HH8526)
5 2-way mini terminal blocks (5.08mm pin spacing)
1 1.5mm panel snap-in male IEC mains connector, with fuse and switch (Altronics P8341)
8 chassis-mount female IEC mains connectors (Altronics P8326)
15 blue fully-insulated 6.4mm female spade crimp lugs
17 red fully-insulated 6.4mm female spade crimp lugs
1 chassis-mount male spade lug
1 5.3mm eyelet crimp lug
20 small nylon cable ties
6 No.4 × 9mm self-tapping screws
22 M3 × 10mm machine screws
24 M3 shake-proof washers and M3 nuts
2 10A M205 fuses (1 spare)
1.2m mains-rated green/yellow (earth) wire
1.1m mains-rated light blue (neutral) wire
0.8m mains-rated brown (live) wire
40cm tinned copper wire
15cm × 2.5-3mm diameter fibreglass sleeving (Jaycar WS5504, Altronics W0852)
Cat5, 5e or 6 cable with length to suit installation

Semiconductors

1 74HC595 serial-to-parallel latch IC (IC3)
1 74HC04 hex inverter IC (IC4)
1 ULN2803 octal Darlington array (IC5)
8 red 5mm LEDs (LED1 to LED8)
8 MOC3021 Triac optocouplers (OPTO1 to 8)
8 BTA41-600B insulated tab 40A Triacs (Triac1 to 8)

Capacitors

2 100µF 16V radial elect.
8 100nF MKT X2 250V AC
2 100nF MKT
8 47nF MKT X2 250V AC
8 10nF MKT X2 250V AC

Resistors

5 10kΩ	8 470Ω
8 360Ω	4 100Ω
8 47Ω	8 39Ω

* Both printed circuit boards are available from the *EPE PCB Service*

The bootloader

The master module firmware includes a 'bootloader'. This allows the software on the master module to be updated without requiring a programming tool.

When the device powers up it looks for a HEX file on the memory card. If it is present, the contents are read and verified, then written into the FLASH program memory.

The main program runs after the programming is complete, or immediately if there is no HEX file. The main program can re-program the bootloader if necessary, allowing the whole chip to be updated.

The FLASH memory is divided in two. The bootloader resides at the end of memory, (addresses 0x9000 – 0xABFF, 10.5kB). The main program is at the start (addresses 0x0000-0x8FFF, 54kB).

The bootloader program incorporates the MMC/SD/SDHC card reader code, along with the FAT file system and FLASH memory programming routines. Because the interrupt vector table is stored in FLASH memory at 0x0000-0x01FF and therefore is part of the main program, the bootloader does not use any interrupts.

The reset vector (which must point to the bootloader) is within the interrupt vector table therefore, when the first page of memory is programmed, the reset vector address is overridden.

If the reset vector were corrupted during the programming process, eg, due to a power failure, the bootloader would no longer work. Before re-programming it, the bootloader program checks that AC power is present via the zero-crossing detection circuitry.

The 2200μF capacitor provides enough power to finish programming even if AC power is lost after that point. A similar check is made in the main program before re-programming the bootloader.

is not activated at the times when IC1 is not operating (eg, when it is powering up or reset).

Input RB5 (pin 12) has a weak internal pull-up enabled. The card socket connects its card detection (CD) pins together if a card is inserted, pulling IC1's pin 12 low and triggering its communication initialisation routine.

Audio output

Audio output is generated from IC1's internal 16-bit DAC and then passes to IC2, a dual op amp. The left/right DAC outputs are differential, meaning that when DAC1L+ swings up, DAC1L– swings low.

For best audio quality, these signals should be subtracted to form the final audio output. IC2a and IC2b are configured as differential amplifiers with a gain of 1.3 (13kΩ/10kΩ), resulting in an output level of around 1V RMS.

The two 10μF capacitors in series with the 13kΩ resistors charge to the DAC's average output voltage and form a virtual ground for the differential amplifier input dividers. They result in a high-pass filter with a –3dB point at around 1Hz.

The 150pF capacitors in parallel with the 13kΩ feedback resistors roll off the op amp gain to form a low-pass filter with a –3dB point around 80kHz.

This active filter removes much of the high frequency switching noise from the delta-sigma DAC architecture, which is mostly above 2MHz (for CD quality audio).

The output of each differential amplifier is AC-coupled to make it ground-referenced, then further filtered with a passive low-pass *RC* filter, consisting of the 100Ω resistors and 15nF capacitors. This is more effective than the active filter at frequencies above IC2's bandwidth (2.3MHz at this gain setting) which can be coupled via the 150pF capacitors.

The 100Ω resistors also isolate IC2's outputs from any cable capacitance and provide current limiting should the outputs be shorted to ground or to each other. CON2 is the audio output connector and accepts 3.5mm stereo jack plugs.

Crystal X1 provides a reference frequency to IC1 for the DAC timing. This allows it to operate the DAC at a frequency very close to the sample rate of the file being played back. IC1 operates at 39.552MHz when the audio sampling rate is 44.1kHz, 22.050kHz (half rate) or 11.025kHz (quarter rate). This is divided by 14, 28 or 56 to provide the DAC oversampling clock, which is 64 times the sample rate. The sample rate error is less than 0.1%.

Alternatively, IC1 operates at 39.936MHz for sample rates of 48kHz, 24kHz (half rate) or 12kHz (quarter rate). This is divided by 52, 26 or 13 (respectively), resulting in exactly 64 times the sample rate. For 32kHz sample rate, the clock is 38.912MHz and the divider is 19, also resulting in an exact DAC clock.

While IC1 runs from the 3.3V supply, its core actually runs at 2.5V. This is generated by an internal regulator. Its output is filtered by the 10μF tantalum capacitor connected between pin 19 and pin 20.

Master to-slave link

The master module communicates with the slave(s) via an 8-pin RJ-45 connector, CON3. This provides the low voltage slave power supply, serial communications and slave chain length sensing. It provides the 3.3V for the slave digital logic (pin 3) and 6V for driving the optocouplers (pin 6) plus a common ground (pin 8).

The same connector is used for the serial communication with data (pin 5) and clock lines (pin 4), chip select/latch (pin 7) and master clear (pin 2). Pin 1 is for chain length sensing and is used by the master module to determine how many slaves are connected. Each slave module has a resistor between this pin and the 3.3V supply, and these form a voltage divider in combination with the 10kΩ resistor on the master board.

Each serial output has a 100Ω resistor between the microcontroller output and the connector pin. This combines with the cable capacitance to form an RC filter which helps to limit reflections and ringing in the cable, as well as reducing electro-magnetic interference (EMI) from the cables by limiting the signal rise and fall times.

Normally, Cat5 cable is used for high speed network signalling and the twisted pairs in the cable are driven differentially. This allows for high speed communication with minimal crosstalk and interference.

However, we are not using differential signalling, so we must limit the serial speed in order to maintain sufficient signal integrity. This is not a problem, as a serial clock of 100kHz is sufficient for this application.

LED1 provides the only direct user feedback from the master module and is driven from pin 2 of IC1. It can be turned on or off, set to an intermediate brightness or flashed at various rates to convey different information to the user.

Slave module circuit

The slave module circuit (Fig.3) receives serial data from the master module to control when each of the eight triacs are

triggered during each mains half-cycle. A 74HC595 serial-to-parallel latch IC (IC3) decodes this serial data. Each of the incoming lines is terminated with a 10kΩ resistor to help to drain the cable capacitance when a line is driven low.

The latch drives a ULN2803 octal Darlington transistor array (IC5), which acts as a current buffer to provide sufficient drive strength for the optocoupler LEDs. These optocouplers (OPT01 to OPTO8) have two purposes. First, they isolate the low voltage signal side of the circuit from the mains side so that lethal voltages cannot be conducted back to the master module over the Cat5 cable (or shock somebody touching the connector).

Second, they make triggering the triacs easy, as all that is required is for sufficient current to pass through their internal infrared LED. The minimum guaranteed trigger current is 15mA and the 74HC595 is not rated to provide this much current directly, hence the Darlington array (IC5). When an output from IC3 goes high, the Darlington in IC5 sinks current via its associated LED, 47Ω series resistor and optocoupler from the 6V rail.

The worst-case voltage drop across each Darlington at 15mA is 1.0V, for the LED around 2.5V and the optocoupler 1.5V. With a the 6V supply rail at 5.7V (due to regulator tolerances and cable drops), this means that the voltage across each 47Ω resistor will be 0.7V resulting in very close to 15mA through the chain.

It's very unlikely that any particular unit will have all worst-case parts, so in reality there is a fair margin for voltage drops across the Cat5 cables. Since the triacs are only triggered for around 5% of each mains half-cycle, the 100µF bypass capacitors in the slave unit should prevent excessive drops on either rail.

Triac control

When the LED in an optocoupler is turned on, its small internal triac will conduct bidirectionally. This allows current to flow from the incoming mains active line (Live), through the 470Ω and 360Ω series resistors and then into the connected 40A triac gate. This will trigger that triac, which will conduct for the remainder of the mains half cycle. Thus, the earlier in the half cycle that the triac is triggered, the higher the RMS current through the load.

Because the triacs have a latching action, the trigger current does not need to be provided for very long. Each trigger pulse lasts for around 0.5ms.

The 470Ω resistors and 47nF X2 capacitors at each optocoupler act to limit the rate of change of the voltage across its internal triac, ie they function as a snubber. This prevents spurious triggering of the internal triac (and hence the associated 40A triac) due to mains noise or electromagnetic interference.

Similarly, the 39Ω resistors and 10nF capacitors connected in series across each BTA41 triac limit the dV/dt rate across the triac terminals to prevent unintentional triggering from mains supply noise and such. This is especially important when the triac is driving an inductive load, such as a halogen transformer, as the switch-off spike when the load is disconnected can easily result in the triac being triggered at the start of the next cycle when it should not be.

The 100µH inductors and 100nF X2 capacitors form an *LC* filter, which limits the inrush current to the load when the associated triac switches on. This is primarily to prevent magnetic radiation from the mains leads connecting each load, which can be quite severe when applying phase control to loads such as incandescent lamps. This is due to the high inrush currents when the filament is cold.

While each triac is rated at 40A, the entire slave module is powered from a 10A input socket with appropriate fuse. In addition, other components in the mains power path (such as the inductors) are rated at 5A, so this is the maximum current per output.

There are two reasons why we are using 40A triacs, despite the much lower continuous rating. The first is that when an incandescent lamp is switched on from cold, its filament resistance is a lot lower than when it is at operating temperature. A 230V AC 150W lamp can be expected to have an overall resistance of around 350Ω at full power. It will therefore draw about 230/350 = 657mA RMS. However when the filament is cold, eg when switched on initially, the resistance can be 10% of this or less. This will result in an instantaneous current in excess of 6A, and even higher for larger lamps or several in parallel.

Even higher currents can occur when a PAR (parabolic aluminised reflector) light fails. The filament can become disconnected at one end and flail around, possibly shorting against the support wires. In excess of 20A can flow before the stem fuse blows. We don't want to burn out a triac under this condition, so we have made sure that they will survive such an event.

One further point regarding the triacs: they only latch with a certain minimum current flow. In the case of the BTA41 this is no more than 80mA. This is the reason why we have specified a minimum load of 25W per output. Otherwise, early or late in the mains cycle when the instantaneous mains voltage is relatively low, the triac may fail to latch, resulting in an incorrect brightness level on that output.

Daisy-chained slaves

The remaining circuitry in the slave module allows for slave daisy-chaining. Up to four slave modules can be connected to a single master module. To ensure that the same length of cable can be run between slave units as can be used between the master and the first slave, we buffer the serial signals using a 74HC04 hex inverter IC (IC4).

The SCLK, LATCH and MASTER CLEAR signals are passed through directly from one slave to the next. Each is inverted twice, in order to buffer the signal but preserve the polarity. As with the master module, there are 100Ω series resistors between the buffer and the output RJ-45 jack.

The serial data stream itself comes from the Q7' output of IC3 and via another 100Ω series resistor. The output from this pin is delayed by eight clocks relative to the serial input.

As a result, when 16 or 32 data bits are shifted through the slave module chain, each serial latch ends up with a different set of eight bits – the first slave latches the first eight, the second slave the second eight, and so on. This allows the master to control each slave individually with a single serial sequence.

That's it for this month. Next month, we will show you how to build the master and slave modules and explain how the firmware and PC software works. We will also provide a location to download the PC software.

Ultrasonic anti-fouling for boats

Part 2: encapsulating the transducer and installation

By LEO SIMPSON and JOHN CLARKE

In the September issue, we published the details of the ultrasonic driver for this project, which is housed in an IP65 case for safety and protection from water ingress. This month, we describe how to encapsulate the ultrasonic transducer so that it is completely safe to handle. Once it is encapsulated it will operate reliably, even if it is submerged in the bilge of the boat. Plus, we sign off with a forum of some readers FAQs (frequently asked questions).

MAKE no mistake. The drive voltage applied to the transducer in this project is enough to give you a severe electric shock.

I speak from painful experience here, having inadvertently touched the top of an exposed transducer while it was under test, prior to 'potting'.

In fact, the shock I received was solely due to my own body capacitance to earth, since I only touched part of the circuit with one finger.

If the total voltage had been applied across both my arms, for example, I might not have been here to write the second part of this article. *So you have been warned!*

THIS PROJECT IS POTENTIALLY LETHAL! For that reason, we have come up with a very specific procedure for encapsulation of the transducer. **Please follow it exactly.**

Preparation

The first step is to obtain everything in the bill of materials, shown opposite. We start with a standard plastic plumbing fitting, available from plumbing outlets.

It is described as a '50mm BSP male valve socket'. BSP stands for 'British Standard Pipe' and you will find it is the same 50mm coarse thread as on the outlet pipe for your toilet cistern.

WARNING!

This circuit produces an output voltage of up to 800V peak-to-peak to drive the ultrasonic transducer and is capable of delivering a severe electric shock.

DO NOT touch the drive unit output terminals, the PC tracks leading to CON2 or the transducer terminals when power is applied.

To ensure safety, the PC board must be housed in the recommended plastic case, while the transducer must be correctly housed and fully encapsulated in resin as described here.

The largest outside diameter of the transducer is close to 44mm and therefore is a close fit inside the 48mm smaller inside diameter of the nominal 50mm male valve socket. The first step in the procedure is to use a rasp or coarse file to create a flat on one side of the plastic fitting. This needs to be done to slightly reduce the wall thickness of the fitting so that we can mount an IP68 6.5mm cable gland on it.

Once the flat has been filed, you need to drill a 12mm hole in the centre of the flattened section to take the 6.5mm cable gland. When fitting the cable gland, you will also need to chamfer the plastic nut on two sides so that it takes up enough thread.

Pass a length of the 2-core black sheathed cable through the gland and strip the wires as shown in Photo 4. The length should be sufficient to be neatly routed from the mounting position of the ultrasonic driver

Bill of materials – encapsulated transducer

1 piezoelectric transducer (Jaycar AU-5556)
1 black plastic flange washer
1 50mm BSP male valve socket (HR-P0175050 or Vinidex equivalent etc)
1 IP65 6.5mm cable gland (one of three required for the whole project)
~10 metres 2-core black flexible sheathed speaker cable (see text) [the same cable should be used for the DC input to the ultrasonic driver box. The exact amount will depend on the length of the boat] (eg Jaycar WB-1754)
1 small jar of petroleum jelly or Vaseline
1 40ml tube of non-hardening silicone grease (eg Fix-A-Tap waterproof lubricant)
1 piece of melamine-coated or Formica-coated pyneboard or MDF (say 150 × 200mm)
1 250g pack of 2-part polyurethane potting resin (Electrolube UR5097)
1 spray can of silicone mould release (Electrolube DAS400)
1 pack of J-B Weld high temperature 2-part epoxy
5 1mm-thick black plastic ‘spacers’ (see text)
4 stainless steel self-tapping screws (to attach ultrasonic driver box to bulkhead in boat)
1 small piece of cling film (say 150mm square)
1 piece of coarse-grade sand/emery paper

Photo 1: before we get under way, here are the chemical products we’re recommending. On the left is the Electrolube polyurethane potting compound, with instructions and the Electrolube silicone mould release. Centre is the Fix-A-Tap waterproof lubricant (available from hardware stores and pool shops) while on the right is the J-B Weld 2-part epoxy glue. It’s not easy to get – but it works!

Photo 2: here we’ve filed a flat on one side of the 50mm BSP male valve socket and drilled a 12mm hole, both of which are needed to accommodate the 6.5mm cable gland through which the wires pass from the driver to the transducer.

Photo 3: Unfortunately, on the threaded end there were some moulding dags – we need the base perfectly flat, so we trimmed these off with a sharp knife and then smoothed it off with some sandpaper.

Photo 4: next, we passed the end of the flexible 2-wire cable through this cable gland, leaving plenty of free wire on the inside. Leave the gable gland nuts loose at this stage to allow the cable to slip in and out.

Photo 5: the 6.5mm cable gland, when tightened up later, makes a completely waterproof entry point for the flexible cable from the driver unit. The recommended cable is double-insulated but still highly flexible.

Photo 6: next, we soldered the two bared ends of the cable to the lugs on the side of the transducer (disconnect from the driver unit first!). Make sure these solder joints are good'uns, because once potted, you won't be able to get at them!

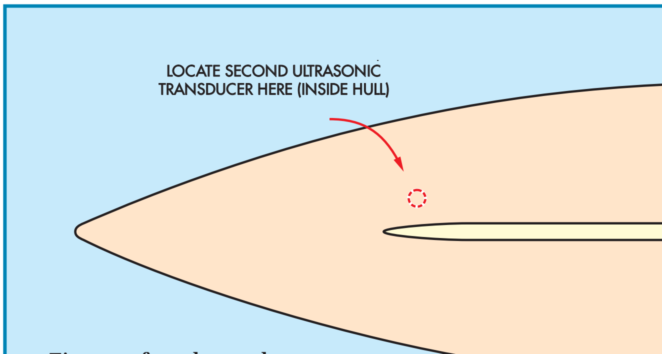


Fig.1: preferred transducer mounting position for typical boat hulls. Catamarans would require one transducer and driver for each hull; boats longer than 14m could require three or four systems.

to the planned mounting position of the transducer in the hull.

We suggest that you make the cable length at least 4m; perhaps more for a very large boat. You can always shorten it at the time of installation. Solder the wires to the transducer, as shown in Photo 6.

When the transducer is positioned inside the plastic valve socket and finally encapsulated, we want the encapsulating material to be no more than 1mm thick over the face of the transducer – therefore the transducer needs to sit up 1mm above the bottom of the socket.

To achieve this, you will need to glue some pieces of black plastic 1mm thick to the face of the transducer. We used Loctite Glass adhesive which cures on exposure to daylight (ultraviolet).

We glued five pieces, but four is probably enough. See Photo 7. These 1mm 'spacers' ensure the right thickness of the encapsulation, which will become evident as we proceed.

Flange it

Next, we work on the black plastic flange, ie, the 'Hansen SBN50LB black plastic flange washer' to make a jig for the encapsulation process.

This flange is a standard unit used on plastic water tank installations and will eventually be used to secure the encapsulated transducer to the hull of your boat.

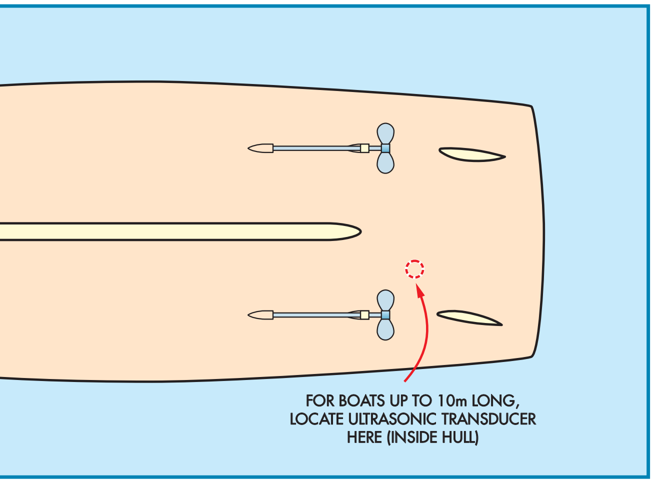
For now, we need to drill four 4mm holes to take 6G self-tapping screws, in the flange section. The flange is then attached to a piece of melamine-coated or otherwise sealed MDF or pyneboard. Before you do that, place a sheet of clingfilm between the flange and the baseboard, as in Photo 8.

Note that the screws used to attach the black plastic flange will be re-used when the ultrasonic driver unit is installed in the hull of the boat.

Having screwed the flange to the baseboard, spray inside the thread of the fitting and the cling wrap with Electrolube DAS400 silicone mould release, as shown in Photo 9.

Make sure the clingfilm is taut and has not become crinkled by the mould release spray.

Screw the male valve socket, with transducer attached by its leads, into the black plastic flange. Do not over-tighten it. You now have a secure jig for the encapsulation process. The transducer should still be outside the valve socket, as shown in Photo 10.



It is now clear why we need the silicone mould release spray. We need to be able to detach the flange from the transducer/valve socket after encapsulation is complete.

Mixing the potting compound

We now mix the encapsulating compound. This requires one 250g pack of Electrolube UR5097 2-part polyurethane resin. It comes in a tough plastic pouch, which is partitioned into two compartments for the resin and the hardener.

You need to remove the plastic fittings from the pouch and then merge the two syrupy liquids together. Knead and roll the bag around for several minutes to thoroughly mix the resin.

Follow the instructions on the pack – although we found mixing took quite a lot longer than the instructions specified (probably because it was a rather cold September day when we did it). But eventually we were happy with the mix – a consistency of runny grease.

Now pour a small amount of the mixed resin into the valve socket so that it covers the bottom surface by a few millimetres. Then insert the transducer face down into the valve socket and push it all the way down. Remember that we want the encapsulation on the face of the transducer to be only 1mm thick. If at all possible, make sure that the transducer has equal clearance all round, inside the valve socket. Photo 7 shows this clearly.

When you are sure that the transducer is correctly positioned, push the leads down so that they will be fully covered by the resin.

Then pour in more resin until its level is just below (say a millimetre or so) the lip of the valve socket. Do not fill it to the brim, otherwise it will overflow as it warms and expands slightly during the curing process.

Leave it overnight to cure. The ambient temperature should preferably be more than 15°C, otherwise the curing process will take too long.

The cured resin is not really hard – it has some 'give' if you press it with a finger-nail. When cured, remove the four screws holding the flange to the MDF and lift it off. It should come away easily.

You should be able to peel the cling film off the face of the finished transducer, leaving a nice clean smooth surface. The finished transducer should look like that shown in Photo 15 and photo 16.

Photo 7: here you can clearly see the five 1mm bits of plastic we glued to the transducer surface to give clearance underneath for the potting compound when it is poured in later. The transducer should be a nice friction fit in the tube – we are just checking everything fits!

Photo 8: to make sure the potting mix doesn't stick to the baseboard, stretch some clingfilm underneath the flange. Remove any wrinkles or bubbles because you want the potting compound to be as smooth as possible. Note the four holes we drilled through the flange.

Photo 9: when you have screwed the flange on to the base board, spray some mould release onto the cling film and also on to the threads of the nut, again to make sure that the potting mix lets go later as it should. You'll probably find that the mould release causes the cling film to wrinkle a little – again, pull the cling film tight to make it smooth.

Photo 10: remove the transducer and screw the empty pipework into the nut. Make it firm, but not so tight that it bites into the cling wrap. You're now just about ready to pot the transducer so make one last check that your solder joints are perfect – once potted, it's very hard to remove !

Photo 11: the potting mix comes in a two-part pack which must first be combined and then thoroughly mixed before use. You need to knead it! On a cool day, this can take quite a few minutes to do, but if you don't mix completely, the compound may not cure properly.

Photo 12: once mixed, cut the corner of the bag off and pour just a small amount – say a couple of millimetres or so – into the transducer housing. Put the bag to one side for a moment (remember to keep the pouring hole up).

Installation in the boat

There are two steps to the installation in a boat. First, determine the optimum position, and install the transducer. Then select the location for the ultrasonic driver unit (last month) and install it.

The driver case needs to be mounted on a bulkhead or other position where it is unlikely to be splashed or immersed in any water which may be in the bilge. We will discuss installation of the transducer first.

Transducer location

As shown in the diagram of Fig.1, the encapsulated transducer must be installed inside the hull, near the running gear (ie, propellers and rudders). On the boat shown in the photos, the transducer was installed in the lazarette, under the floor of the transom. First, you must find a suitable flat section of the hull; on many boats, this will not be easy. Try positioning the black plastic flange (ie, without the transducer fitted) in a number of positions to get the best spot. Let us now go through the steps for installation.

Using coarse sandpaper and a sanding block, roughen the face of the black plastic flange, as in Photo 17. We want a good 'key' for the epoxy resin.

Use the sandpaper and sanding block to thoroughly scour the hull position where the black flange is to be mounted. Photo 19 shows the plastic flange temporarily in position on the hull after it has been sanded.

By the way, it is essential that the mounting area for the flange must be clean and dry, and free from dust and grease. And of course, there should be no possibility of exposure to bilge water while the epoxy resin is curing.

Mix a quantity of J-B Weld High Temperature 2-part epoxy resin. Do not use Araldite or any other epoxy mixes. We want to be sure of a reliable long-term bond to the hull, which won't let go with constant ultrasonic vibration. See Photo 20.

Apply a liberal coating of petroleum jelly (or Vaseline) to the thread of the plastic flange, as in Photo 18. We don't want any epoxy resin to adhere to the threads, otherwise the flange will not be usable.

Apply the mixed epoxy resin to the roughened surface of the flange, as in Photo 21. Then press it down onto the previously prepared section of the hull. Leave it to set for 24 hours. If the water (and therefore the hull) is very cold (eg, midwinter), leave it for longer.

Some adhesive will probably ooze out from under the flange – outside the flange it doesn't matter too much (apart from aesthetics). Inside, though, it should be carefully cleaned away without getting it on the threads so that the transducer (when fitted) will not sit proud of the hull.

Installing the driver unit

The next step is to install the ultrasonic driver module (last month). Its IP65 plastic case has provision for four mounting screws. To fit them, you need to remove the transparent lid of the case and position the unit in the spot where it is to be mounted. Preferably, it should be on a vertical bulkhead above the waterline, say between the engine compartment and the lazarette.

On the boat in the photos, this was not possible, so it was positioned on the horizontal beam which carries the hydraulic drive to the rudder (Photo 24).

It is most important that the ultrasonic driver unit be mounted above any likely spray or splashes from water in the bilge. On no account should you drill holes in the hull to mount the ultrasonic driver – that carries too much risk of you drilling right through the hull!

Photo 25 shows the ultrasonic driver being mounted in place. Use stainless steel screws – you can recycle those you earlier used to make the encapsulation jig.

Having mounted the ultrasonic driver in place, we now need to position the encapsulated ultrasonic transducer next to its mounting flange in the hull of the boat. Inevitably, this will involve running its cable through inaccessible holes in parts of the boat structure. If you can run the cable next to existing cable, so much the better. Lace the cable into position where necessary. It should not be allowed to flap about or hang in loose loops. Remember that boats experience severe vibration, and we don't want the cable to fail in the long term (Photo 27).

You may have to drill holes in bulkheads to run the transducer cable through. Make sure those holes do not have rough edges which can chafe the cable. If they do, fit suitable grommets.

Meanwhile, back at the hull

Now that the J-B Weld has cured, we can return to the transducer mounting.

First, liberally coat the face of the encapsulated transducer with a non-hardening grease. This is applied to fill any voids when the transducer housing is screwed down into the flange.

Before screwing in the transducer housing (a conventional clockwise thread), twist the housing anticlockwise the same number of turns as it takes to screw it in so that when the transducer is installed, the cable is in its natural (untwisted) position. Do not over-tighten it, but make sure that it is tight enough that it is not likely to shake loose over time.

Make sure that the transducer cable is neatly routed and cannot possibly interfere with the operation of any moveable parts, such as the rudder gear.

Finally, you need to make the supply connections to the house battery. Again, lace and anchor the supply cable securely. There is no need to fit an in-line fuse because there is already a 3A fuse on the PC board.

Note that since we are making a permanent connection to the battery, it must have a float charger or preferably, a 3-state charger so that it is always kept charged.

When power is applied, the green LED can be seen to be glowing through the transparent lid of the case.

Turn it on… and nothing!

You probably won't know that it's operating, but if you want to check that the circuit is active, just position a portable AM radio next to the driver and you should hear it squealing away. As discussed in the FAQs (overleaf) there may be some who will hear a few clicks or whistles but these would be unusual.

OVERLEAF: Answers to the many questions we've already been asked about this system!

Photo 13: now push the transducer hard down, into the potting mix, face down. About now you might find out that overfilling with potting mix makes a nice mess of your thumbs . . . try to get the transducer as centrally located in the tube as possible, although it's not vital. Pull the cable back through the grommet until about 10mm of outer insulation is showing inside, then tighten the nuts.

Photo 14: squeeze the potting compound out like toothpaste – not too fast, to be sure you don't get any bubbles trapped. Fill to a millimetre or so below the top of the tube – as it cures, it warms and expands. We found we used most of the 250g pack of resin.

Photo 15: when cured and removed from the jig, this is what it will look like (hopefully without the air bubbles, although these won't affect operation). The top of the potting compound is just below the top of the fitting.

Photo 16: and here's what it looks like from the underside (the bit that contacts with the boat hull). The 'rough' edge on the socket is actually a smooth edge – we removed some thread ends with sandpaper.

Photo 17: now we're moving onto the installation in the boat. After you remove the black plastic flange from your temporary jig, roughen the bottom with some coarse sandpaper. This is to give a good 'key' for the adhesive to ensure it won't vibrate loose when fixed to the boat hull.

Photo 18: it's important that glue doesn't get into the thread, where it would clog it up. We smeared a good coating of Vaseline right around the threads – make sure it doesn't get on the bottom of the flange where you *want* the glue to take!

Ultrasonic Anti-Fouling FAQs

The first article on ultrasonic anti-fouling for boats has prompted a deluge of questions from readers who could not wait until the second article. So here are the answers.

Q: How big a boat?

A: The single transducer driver and design presented here is suitable for boats up to 10 metres long. Longer boats, say up to 14 metres, will require two transducers, each with its own driver unit. Boats bigger than 15 metres, say up to 20 metres, will require at least three and maybe four transducers and drivers.

Catamarans up to 10 metres long will require a separate transducer and driver unit for each hull.

Q: Do I need to cut a hole in the hull for the transducer?

A: Definitely not – the encapsulated transducer is mounted on a flat surface inside the hull. For a boat up to 10 metres, the transducer should be mounted near the running gear (ie, propellers and rudders) so that it offers maximum protection from marine growth.

Q: Is ultrasonic anti-fouling suitable for all boats?

A: Ultrasonic anti-fouling relies on one or more transducers mounted inside the hull to excite it at various frequencies in order to disrupt the cell structure of algae. It works well with metal hulls such as aluminium and with fibreglass hulls. It does not work with timber hulls, as the timber is not a good conductor of ultrasonic energy. The same comment applies to ferro-cement or fibreglass hulls with a balsa sandwich or other composite construction (eg, closed-cell PVC foam).

Q: Does the ultrasonic anti-fouling unit present a risk of electric shock?

A: As stated in the circuit description, the ultrasonic transducer is driven with peak voltages up to 800V. If you make direct contact with the circuit or the ultrasonic transducer there is a very high probability that you will receive a severe electric shock. That is why the transducer itself must be completely encapsulated in a plastic fitting, as described elsewhere in this article.

Q: Is it necessary for the boat's hull to be cleaned of marine growth and conventionally anti-fouled before the ultrasonic anti-fouling system is installed?

A:Ultrasonic anti-fouling is unlikely to kill shell fish or molluscs already attached to the hull. Nor will it cause them to detach from the hull. Hence, there is no alternative to having the hull scraped and water-blasted to clean off all existing marine growth.

And if it is already on the slips for such cleaning and other maintenance such as servicing outboard legs and replacing sacrificial anodes, it probably makes sense to have conventional anti-fouling paint applied, although this may be regarded as optional.

We should also emphasise that, no matter how effective ultrasonic anti-fouling may be in keeping the hull clean of marine growth, it will still be necessary to do regular maintenance such as the already mentioned servicing of outboard legs (in case of boats with inboard/outboard motors) and replacing sacrificial anodes.

Q: Will ultrasonic anti-fouling keep propellers, rudders and other 'running gear' free of marine growth or is it still necessary to use anti-fouling compounds such as PropSpeed?

A: Ultrasonic anti-fouling should keep props and rudders free of marine growth. Overseas experience with commercial units has shown this to be the case.

Q: Does ultrasonic anti-fouling cause increased electrolytic leakage currents (electrolysis) and thereby increase corrosion on boats?

A: The ultrasonic transducer and driver unit are installed entirely within the hull of the boat and the ultrasonic transducer itself is transformer driven and is completely encapsulated to provide a high degree of insulation. There should be no leakage currents at all.

Q: Does ultrasonic anti-fouling harm fish or marine mammals?

A: This system causes no harm to fish or to marine mammals. Fish cannot hear it and while marine mammals certainly can perceive and respond to ultrasonic signals, they are not harmed in any way by the relatively low power levels which are likely to be radiated by the hull of the boat. Furthermore, the signal levels are much lower than those directly radiated by depth sounders and fish finders.

Q: Will I be able to hear the ultrasonic anti-fouling unit in operation, especially at night when the water is very still?

A: Unless you are a bat(!), you cannot hear ultrasonic frequencies directly. However, the transducer and the driving transformer do emit high frequencies and clicks

– continued

Photo 19: move the empty flange around the hull to determine the best transducer mounting position. When you're happy with your choice (see the text), roughen the fibreglass as you did the black flange – for the same reason. Here the flange is sitting in place but not yet glued.

Photo 20: did someone mention glue? We're recommending J-B Weld to secure the flange to the hull. It's not that easy to buy (try your local hardware store as distinct from the big chains) and it's not cheap – but it sticks like the proverbial.

Photo 21: apply a good layer of mixed glue all over the roughened base of the flange, again making sure you don't get any on the thread. You have quite a while before it starts to cure, so take your time!

Photo 22: it's almost inevitable that there will be some J-B Weld oozing out from under the flange as you press it in place. The secret is to apply only as much pressure as is really needed to ensure the glue spreads right around, then wipe any excess off before it sets.

Photo 23: once set (24 hours +), the transducer assembly is screwed into position with a good big dollop of Fix-A-Tap lubricant on the face. But before doing so, wind it anti-clockwise a number of turns so that the cable ends up without loops or kinks. Screw down as hard as you can with your fingers, but don't force it. Lace any loose cables.

Photo 24: the location for the driver unit is just as important as the transducer. It must be one which can NEVER interfere with any boat operation and one which won't be stepped on if you need to get into the area. Just as important, it must be one which won't be swamped by bilge water, despite the IP65 case.

Ultrasonic Anti-Fouling FAQs

at low levels. These are actually sub-harmonics of the ultrasonic signals and are most evident as the frequencies are continuously shifted up and down over the operating spectrum.

However, once the unit is installed, you will only be able to hear these sounds, if at all, by placing your ear directly over the ultrasonic driver or over the transducer. You might also be able to feel some slight vibration of the transducer itself.

Q: Is ultrasonic anti-fouling equipment likely to cause damage to the hull of a boat, especially those of fibreglass construction? Will it cause osmosis or de-lamination?

A: We know of no research into this topic and while it could be suggested that the continuous, albeit low-power, ultrasonic vibration of the hull could lead to de-lamination, such ultrasonic vibration is extremely low in amplitude compared with the severe hull vibration caused by propellers and diesel or petrol motors when boats are operating at high power, especially when 'on the plane'. Furthermore, hulls are placed under very high stresses when boats are being pounded by heavy seas or are repeatedly slammed though waves or hitting wakes of other boats at speed.

Many older fibreglass boats, say more than 20 years old, are subject to osmosis and de-lamination. Repairs are routine but expensive to carry out and the boat must be out of the water for many months to ensure that any water trapped in hull laminations is removed.

If a boat was fitted with ultrasonic anti-fouling and after years of use, there is subsequent evidence of hull osmosis or de-lamination, it would be impossible to determine if it were caused by normal wear and tear or other causes.

Ultrasonic anti-fouling is routinely fitted to brand new boats, but anyone contemplating such an installation would be wise to check that hull warranties are not invalidated. We make no warranties that ultrasonic anti-fouling does not cause hull damage.

Q: Will my boat batteries be damaged by the ultrasonic driver unit?

A: The ultrasonic driver circuitry described last month incorporates battery protection. If the battery is discharged to 11.5V, the circuit is disabled and will not resume operation until the battery is recharged.

However, since the ultrasonic anti-fouling driver is designed to operate continuously, the battery supplying it will need to be on permanent float charge. This will require 230V AC shore power if you are fortunate enough to have your boat in a pen or marina berth.

– continued

If your boat is on a swing mooring or is otherwise without shore power, then a solar panel and suitable charger will be needed to keep the battery up to charge. We plan to publish a suitable solar charger with MPPT (maximum power point tracking) in a future issue.

Q: How big a solar panel will be required to keep the battery sufficiently charged?

A: The continuous power drain of the ultrasonic driver is about 3W or less, depending on the actual supply. However, the peak powers are much higher, at around 40W or more. To provide this level of power on a continuous basis you will need a solar panel installation of at least 20W. Many boats on swing moorings would already have such a solar panel, but it would need to be augmented by at least another 20W to be sure that the battery is fully charged during periods of bad weather or in winter when there are fewer hours of sunlight.

Can the ultrasonic driver feed two or more transducers?

A: The ultrasonic driver presented here can definitely only drive one transducer. Connecting it to two transducers in parallel will overload both its transformer and the driving MOSFETs. In addition, each transducer needs its own separate transformer to drive it, so that it can resonate independently of other transducers. This is necessary to obtain maximum efficiency from each transducer.

While it is certainly possible to produce a design with more than one transformer in order to drive two transducers (or three transformers to drive three transducers), the resulting design would require a much larger PC board and IP65 case. This would inevitably mean that it would be more difficult to mount in a boat, since space is always at a premium.

In addition, in a larger boat installation, having multiple single ultrasonic drivers and transducers confers an extra degree of reliability with virtually no penalty in terms of battery drain.

Q: Will the ultrasonic anti-fouling cause interference to radio operation on my boat?

A: If you place a portable AM radio on top of the ultrasonic anti-fouling driver unit, you should be able to hear evidence of its operation as a continuously shifting squeal. However, at even small distances away from the driver, such interference should be negligible. No interference will be caused to marine radio communications or to broadcast FM or TV reception, or to digital TV or DAB+ reception.

Q: Will the ultrasonic anti-fouling unit interfere with the operation of depth sounders or fish finders?

A: No. *EPE*

Photo 25: Use the case itself (with the lid off) as a template to mark your drilling positions, then move the case and drill the holes to mount the driver electronics.

Photo 26: remember those four stainless steel self-tappers we told you not to discard? They're perfect for securing the case to its mounting position. A power screwdriver is a good idea here: we didn't have the right bit and screwing into the fibreglass was really tough going.

Photo 27: after mounting, connect to an appropriate battery (one that receives shore power or solar panel charging). Dress the leads so that they can't move around or vibrate (remember that there are severe stresses and forces at work in a boat, especially at speed). Use small cable ties to lace the cables to existing wiring.

Max's Cool Beans

By Max The Magnificent

I recently received an email from someone who said he had a business idea he wanted to run by me.

The idea was to be able to rent robot avatars. The way he described it was as follows. Let's assume I wished to attend a conference in London, but I didn't have the time or money to fly over from the US. Now, suppose there was a 'Rent an Avatar' company in London. So I call up and say 'I want to rent an avatar to attend the XYZ conference at Earl's Court next Wednesday.'

On the day in question, they drop my avatar off at the conference. Now, I can remotely control the little rascal via the Internet from my office computer – seeing what it sees and hearing what it hears. Also I can use it to talk to people at the conference, and so forth.

What could you do with one?

Initially, I have to say that my knee-jerk reaction was less than enthusiastic, but then I started to think about this some more. For example, I live in America, while my dear old mum lives in England. Of course, we talk on the phone all the time, and we could always set up a video connection on Skype (if I could persuade her to use Skype). But suppose I had a robot avatar in her apartment with an iPad-size display for a head showing my smiling face; something that could follow her into the kitchen when she made a cup of tea, and that we could use to have conversations with each other. I've talked with her about this, and she agrees that it would be much more like 'having me there' sort of thing.

Or what about the fact that she had to go into hospital at the beginning of this year, but we weren't given the 'go-ahead' until it was too late for me to be there. I called her every day on the phone, but if the hospital had provided robot avatars for hire, I would have jumped at the chance.

Suppose I had a robot avatar at home. When my son returned from school if I was still at the office, I could use it to make sure that he did his homework and even help him if he had a question. In fact, the more I think about it, the more I realise just how useful these little scamps could be.

What's out there?

When I was first presented with the robot avatar idea, I thought 'Hmmm, sort of an interesting concept, but we are a long way from having this sort of capability.' But then I decided to have a look around the Internet to determine the current state-of-play with regard to this sort of thing, and I was somewhat surprised by what I discovered.

First of all, there are some mega-complex systems that are still in the realm of academia or research and development. One example of this class is the Telesar V robot Avatar, which is being developed by the folks at Keio University in Tokyo. This really is pushing the limits of what is currently possible. For example, you use a virtual reality headset to see what the robot sees through its dual (binocular) cameras, and hear what it hears via its binaural microphones. Also, you can control its hands using special gloves with feedback mechanisms that allow you to 'feel' what the robot is touching (here's a video on YouTube **www.youtube.com/watch?v=ZMF0p15GPYg**).

Obviously, this is way beyond anything I could afford to purchase or would have any chance of building at home. But it turns out that there are much more affordable and realistic options, like the VGo from VGo Communications (**www.vgocom.com**). I talked to the folks at VGo, and it seems that their robot avatars are already being deployed in all sorts of environments, including hospitals and schools.

In the case of schools, children who have crippling allergies, or other illnesses that prevent them going in person, can still attend classes via their VGo. Furthermore, they can use the VGo to hang out with their friends during breaks and suchlike. This isn't just 'pie in the sky' – it's really happening and it's happening now!

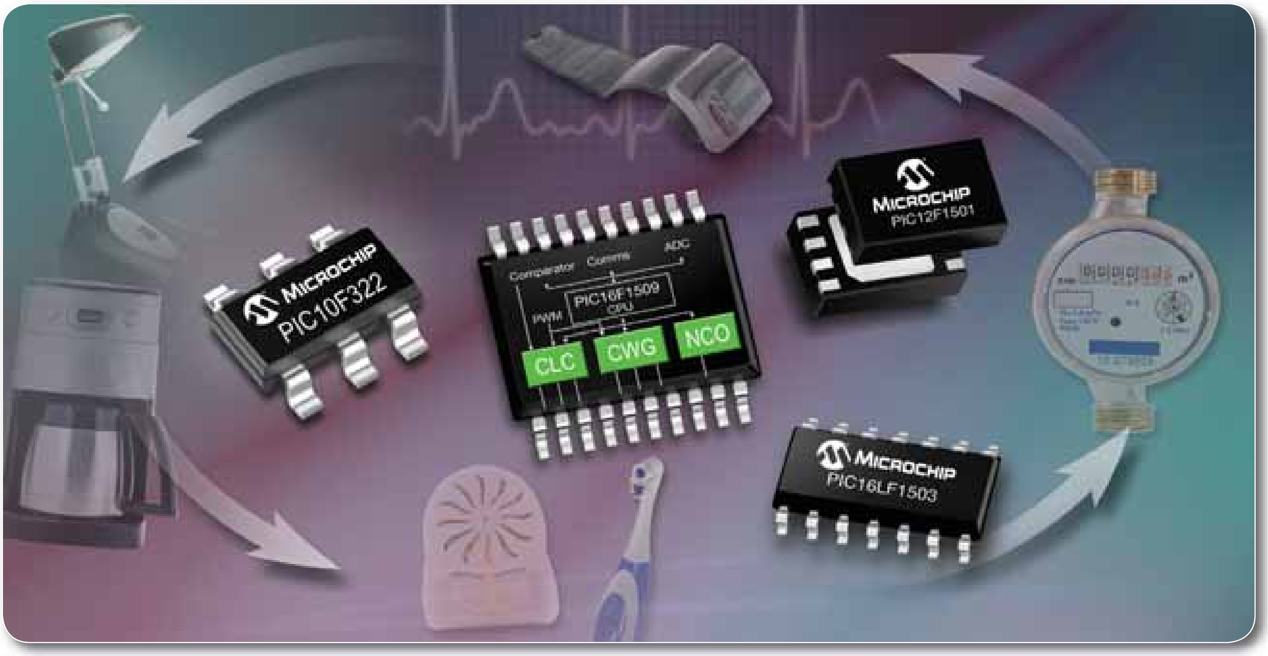
VGo goes to school (www.vgocom.com)

Building an open source robot avatar

Sad to relate, even the VGo is beyond my humble resources, but all is not lost, because I recently became editor-in-chief of a new web-based community for programmable technology (**www.All-ProgrammablePlanet.com**). One of the projects we are working on is to create our own open source Robot Avatar.

The main thing is that people will be able to build this little beauty for themselves. Also of interest is the fact that we are still in the early days of this project, throwing around different ideas and trying to tie down the specification, so now would be a great time to bounce over to All Programmable Planet and join in the fun. I love this stuff!!!

New 8-bit Microcontrollers with integrated configurable logic in 6- to 20-pin packages



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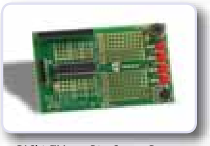

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Designing and Installing a HEARING LOOP For the deaf

Part 2: By JOHN CLARKE

Last month, we introduced the subject of hearing aid inductive loops and explained how they were designed. We also mentioned that most amplifiers could be used to drive hearing loops, albeit with a bit of tweaking in most cases. Now we move on to some of the commercial equipment designed specifically for driving hearing loops.

AS WE explained last month, the vast majority of build-it-yourself and commercial (hi-fi and PA) amplifiers are *voltage* amplifiers, whereas hearing loop amplifiers are *current-operated* devices. That's not to say you can't use a voltage amplifier on a hearing loop – you can, with appropriate treble boost to compensate for rolloff in signal strength due to loop inductance.

But typical amplifier treble controls are not suitable, because they do not operate at the correct frequency. There is a better way, and that is to 'pre-condition' the audio feed to the amplifier – and we'll shortly be describing such a device. It's quite simple and relatively cheap (especially if that means you don't have to buy a new hearing loop amplifier).

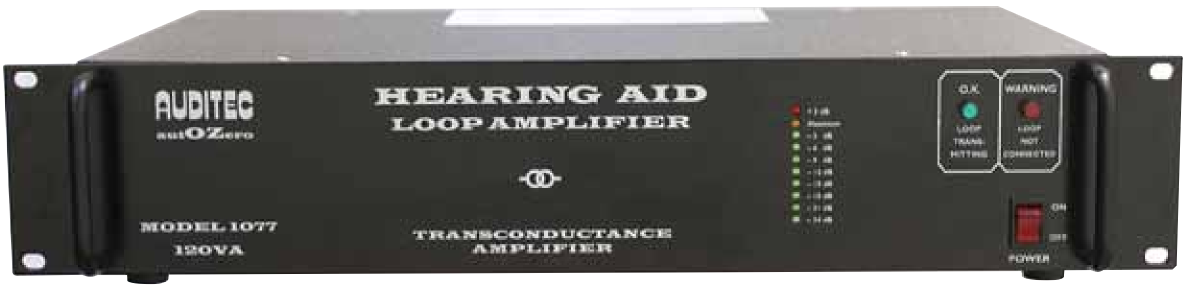
This month, we're going to look at some of the commercial hearing loop amplifiers often found in public buildings. These are the ones often installed by professional organisations who are these days fitting out most new buildings and retro-fitting olders ones.

Auditec hearing loop amplifiers

The Auditec (**www.auditec.com.au**) range of hearing loop amplifiers is an example of what is available commercially. The Auditec 1077 amplifier shown here is housed in a 2-unit rack mount case. Lower powered amplifiers are built into a smaller instrument-style case. They are available from Bavas Music City, (**www.bavasmusic.com.au**).

The amplifiers include signal compression (to maintain a more constant signal level), a bargraph loop level display, and loop disconnect indicators. The frequency response of the amplifiers is from 100Hz to 5kHz. The table opposite shows the amplifiers that are available, and the size of the loop that each amplifier can drive.

The 1077 amplifier for example, can drive a loop that has a maximum perimeter of 150m. This equates to a maximum loop size of 15m × 60m or 20m × 55m or similar, but note that the smaller dimension must not exceed 20m. So you cannot use a 37.5m square loop. Minimum loop size is 10m × 10m, and that equals the minimum loop perimeter of 40m.



Auditec's model 1077 transconductance amplifier (another way of saying current amplifier) designed specifically for hearing loop use. It can drive a loop between 40m and 150m long.

Auditec's model 1077 – at first glance, there is not much to distinguish it from a conventional (voltage) PA amplifier. The 1088 and 1099 models also include a separate 10W amplifier for loop monitoring via a local speaker. The table below shows various loop sizes and lengths for Auditec hearing loop amplifiers.

The wire used is 2 × 24/0.2mm figure-8 wire, connected in series to form an effective two turns around the loop.

Each amplifier includes a bargraph level display to enable the loop level to be set correctly. The level is set so that the orange LED just lights on loud levels, but without the red LED lighting. It appears that the amplifier displays the signal level based on the total resistance of the loop and that the listening height above the loop is assumed to be in the seated position above a floor mounted loop.

Table 1: Auditec model and hearing loop drive details

Model	Power (VA)	Maximum total loop length (m)	Minimum total loop length (m)	Maximum width across the narrow side (m)
1044	20	40	20	5
1055	60	80	20	15
1077	120	150	40	20
1088	120	150	40	20
1099	300	400	40	30

Loop power

As explained last month, loop power is dependent upon loop size and height above the loop to produce the necessary field level. You may require a lower loop current if the length of wire used for the loop does not make up the total length. So, for example, if you have a loop that is 10m × 10m, but the total wire length is not 40m as you would expect for a 10m × 10m square loop but is, say, 60m. This extra wire length is used to reach the amplifier that is not located nearby the loop. For this setup, the signal level display may differ from the true level.

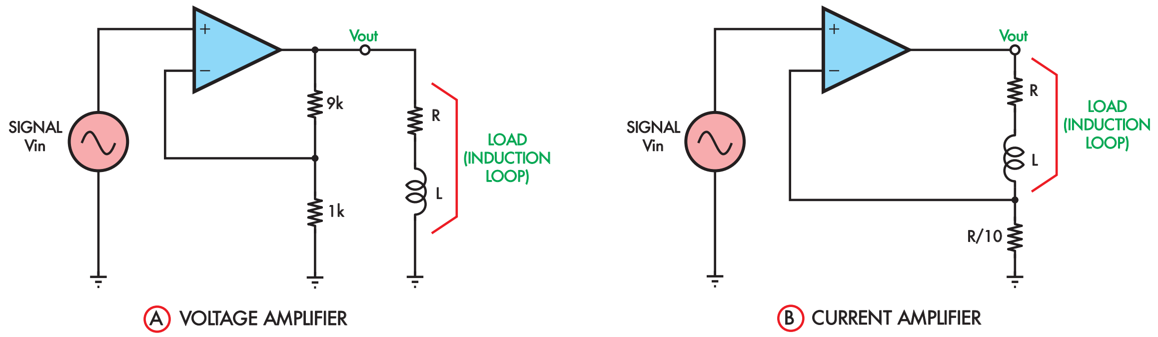


Fig.15a (left): repeated from last issue, a voltage amplifier driving a hearing aid loop load will produce less current in the loop with rising load impedance. Fig.15b (right) : a current amplifier driving a hearing aid loop load will maintain current in the loop with rising loop impedance.

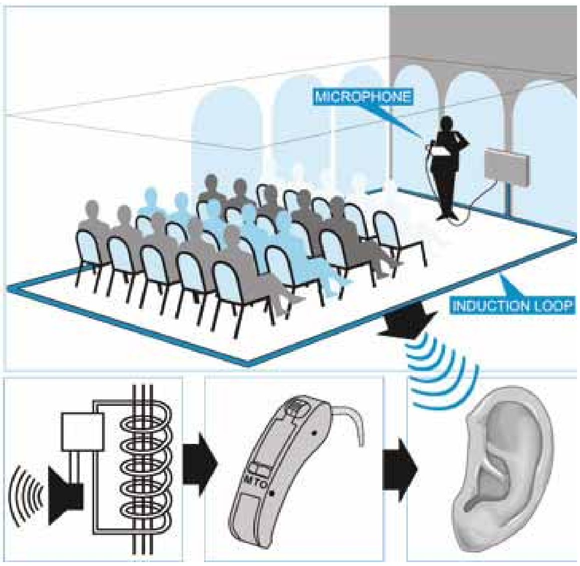
Last month, we described a build-it-yourself hearing loop receiver, but if you aren't inclined to build your own, here's a commercially available receiver for use with headphones (available from Moore Hearing (*www.moorehearing.com.au*). Even if you don't have a hearing loss, a hearing loop receiver is handy when you're setting up the loop, to monitor for sound quality without the need for assistance from a person with a T-coil-fitted hearing aid.

Ideally, for any hearing loop setup, the field strength should be monitored using a field strength meter to ensure the level is correct. We will be publishing a suitable level meter in a future issue.

You may require a higher-powered amplifier if the height above (or below) the loop is significant compared to the loop size. More detail about extra power requirements for height above or below the loop is in the voltage amplifier section (see last month's article).

Voltage and current amplifiers

Fig.15a shows the configuration of a voltage amplifier with a gain of 10. It is based around a high-gain amplifier with negative feedback between the output and inverting input. The output voltage is divided by 1kΩ/(1kΩ +9kΩ) and so overall the division is by 10. This divided signal is applied to the inverting input and the output is adjusted so that the inverting input is at the same voltage as the non-inverting (+) input. Gain of the overall signal from input to output is 10. Gain can also be calculated by the equation 1+ (9k/1k).



A practical PA system incorporating a hearing loop. This church setup consists of a Redback (Altronics) diversity UHF wireless microphone receiver, a foldback amplifier sitting on top of the Auditec hearing loop amplifier. Underneath are two 120W front-of-house amplifiers with a small audio patch box just visible on top of them.

The output drives the load between V_{OUT} and ground. Voltage output is independent of the amplifier load assuming the amplifier can drive the load.

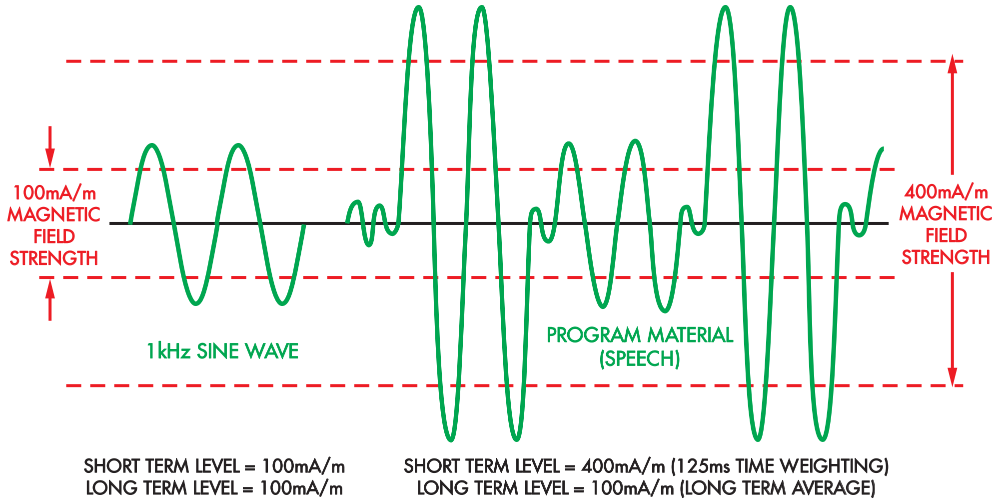
If this amplifier drives a hearing loop, then for a fixed signal level, the current through the hearing loop will vary with the load impedance. Since the load comprises a resistance and an inductance, the effect of the inductance will be to increase load impedance with frequency. See the section 'Loop Inductance' (last month) for more detail. The current through the loop will therefore fall with increasing frequency.

For example, if the overall load impedance doubles to become *2R*, the load current will be halved compared to if the load is just *R*. To maintain a constant current in the load with rising load impedance, the applied input signal needs to rise with frequency.

With the current amplifier configuration shown in Fig.15b, the load is a part of the feedback network. At low frequencies, the impedance of the load is just the resistance [*R*] and so the division of the output voltage applied to the inverting input is (*R/10*)/(*R* +*R/10*). Gain between the input and output is therefore 11.

Note, however, that the signal across the load is less than the full V_{OUT}. This is because the load is not between V_{out} and ground, but is via the *R/10* resistance. Therefore, only

Fig.16 shows the magnetic field strength for a sinewave at 100mA/m. Program material is set for the same level using a long time measurement. Peak levels for the program material will reach 400mA/m measured with a 125ms weighting.



10/11ths of the signal at Vout is across the load. The remaining 1/11th of the signal is across the *R/10* resistor, this represents a small power loss. Overall gain as far as the load is concerned is therefore 10, the same as the voltage amplifier.

Another way of looking at this is to note that the voltage signal at the input (V_{in}) will be the same as the voltage across the *R/10* resistor. When the load is just *R* at low frequencies, the signal through *R* is 10 times the V_{in} signal.

Because the load impedance is a part of the feedback for the amplifier, any changes in the load impedance will alter the gain. So for example, if the overall load impedance is doubled to become *2R*, amplifier output is V_{in} × (*2R +R/10*)/*R/10* and that simplifies to 21. The signal across the load is 20 times the input (*2R/R/10*).

Therefore, the voltage across the load doubles when the load resistance doubles. This maintains a constant load current regardless of the load impedance. So a current amplifier automatically increases the voltage across the load as the load impedance increases.

With any amplifier, the output must be able to maintain the voltage swing required to provide the gain of the amplifier. This depends on the power and voltage swing available from the amplifier.

Ampetronic design guide

As mentioned last month, details on suitable loop designs with steel buildings can be obtained from Ampetronic (**www.ampetronic.com**). They provide a design guide for induction loops that includes information on spill control and loop arrays. The image at left is taken from this guide.

One thing to note is that this design guide **misinterprets** the field strength requirement for the hearing loop. The Ampetronic design guide incorrectly states that: '*the magnetic field strength must be 400mA/m ±3dB across the volume of use. This is the reading with 125ms RMS measurement with a 1kHz sinewave applied to the system.*'

The standards specifically state that the field strength should be 100mA/m (within 3dB), as created by a 1kHz sinusoidal signal. It is only with normal program material (such as in speech) where the 400mA/m level will be reached, and this is during peaks in level using a time-weighted measurement of 125ms. Long time measurement of the program material should equal the sinewave level.

Setting the long time average field strength level to 400mA/m may provide better results in induction loop receivers because the signal-to-noise level is improved by 12dB. However, this is not the standard level and at this level it is likely to cause a hearing aid to overload, particularly during signal peaks.

Hearing loop standard

The hearing loop and designs in this article conform to the current specifications for hearing aids entitled: *Magnetic field strength in audio frequency induction loops for hearing aid purposes*. Details are available in European standard IEC 60118-4 Ed. 1.0 (1981) and the Australian and New Zealand standard AS60118.4-2007. Both European and Australian/NZ standards have the same specifications.

Hearing loop magnetic field strength levels are recommended to be at 100mA/m. This is for a 1kHz sinewave signal. The level for program material when measured over a long time period should equal this sinewave level. The program material is expected to vary by 12dB in level using a 125ms time weighting. Measured peaks will therefore rise to 400mA/m. The same 125ms time weighting for the sinewave signal will remain at 100mA/m.

Fig.16 shows the magnetic field strength for a sinewave at 100mA/m. Program material is set for the same sinewave level using a long time measurement. Peak levels measured with a 125ms weighting will reach 400mA/m. Note that the sinewave level will remain at 100mA/m with either time weighting measurement over 125ms or long time.

Values for maximum background environmental field strength and loop frequency response are also provided in the AS60118.4-2007 standard. Standards are available from SAI Global at **http://infostore saiglobal.com/store/**

Jump Start

By Mike and Richard Tooley

Design and build circuit projects dedicated to newcomers, or those following courses taught in schools and colleges.

WELCOME to *Jump Start* – our new series of seasonal 'design and build' projects for newcomers. *Jump Start* is designed to provide you with a practical introduction to the design and realisation of a variety of simple, but useful, electronic circuits. The series will have a seasonal flavour, and is based on simple, easy-build projects that will appeal to newcomers to electronics, as well as those following formal courses taught in schools and colleges.

Each part uses the popular and powerful 'Circuit Wizard' software package as a design, simulation and printed circuit board layout tool. For a full introduction to Circuit Wizard, readers should look at our previous *Teach-In series*, which is now available in book form from Wimborne Publishing (see *Direct Book Service* pages 75-77 in this issue).

Each of our Jump Start *circuits include the following features:*

- ***Under the hood*** **–** provides a little gentle theory to support the general principle/theory behind the circuit involved
- ***Design notes*** **–** has a brief explanation of the circuit, how it works and reasons for the choice of components
- ***Circuit Wizard*** **–** used for circuit diagrams and other artwork. To maximise compatibility, we have provided two different versions of the Circuit Wizard files; one for the education version and one for the standard version (as supplied by *EPE*). In addition, some parts will have additional files for download (for example, templates for laser cutting)
- ***Get real*** **–** introduces you to some interesting and often quirky snippets of information that might just help you avoid some pitfalls
- ***Take it further*** **–** provides you with suggestions for building the circuit and manufacturing a prototype. As well as basic construction information, we will provide you with ideas for realising your design and making it into a complete project
- ***Photo Gallery*** **–** shows how we developed and built each of the projects.

Coming attractions

Issue	Topic	Notes
May 2012 ✓	Moisture alarm	Get ready for a British summer!
June 2012 ✓	Quiz machine	Revision stop!
July 2012 ✓	Battery voltage checker	For all your portable gear
August 2012 ✓	Solar mobile phone charger	Away from home/school
September 2012 ✓	Theft alarm	Protect your property!
October 2012 ✓	Wailing siren, flashing lights	Halloween "spooky circuits"
November 2012	Frost alarm	Beginning of winter
December 2012	Mini Christmas lights	Christmas
January 2013	iPod speaker	Portable Hi-Fi
February 2013	Logic probe	Going digital!
March 2013	DC motor controller	Ideal for all model makers
April 2013	Egg Timer	Boil the perfect egg!
May 2013	Signal injector	Where did that signal go?
June 2013	Simple radio	Ideal for camping and hiking
July 2013	Temperature alarm	It ain't half hot ...

Spooky circuits

In this month's Jump Start *we will be designing and building some 'spooky circuits' to help you celebrate Halloween in style!*

Under the hood

Our spooky circuits produce various strange sounds and lights, and they are all based on circuits that use a standard 555 timer chip operating as an astable oscillator (this simply means that the circuit has no stable state. Its output will continuously flip backwards and forwards, changing from one state to another).

The 555 timer is without doubt one of the most versatile integrated circuit chips ever produced. Not only is it a neat mixture of analogue and digital circuitry, but its applications are virtually limitless in the world of digital pulse generation.

The standard 555 timer is supplied in an 8-pin dual-in-line (DIL) package with the pinout shown in Fig.1. The simplified internal arrangement of a

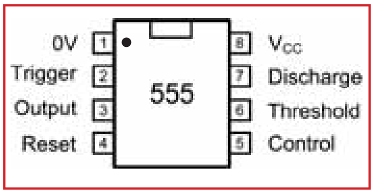


Fig.1. Pin connections for a standard 555 timer IC

standard 555 timer is shown in Fig.2.

Note that the internal circuitry of the 555 uses both analogue and digital techniques. For example, IC1 and IC2 are operational amplifiers used as comparators, while IC3 is a bistable flip-flop and IC4 is an inverting buffer. We will be meeting all of these circuit building blocks again in later instalments of *Jump Start* so we will save their detailed explanation until then!

How it works

The 555 timer can be configured in various ways, including both monostable and astable operation. Fig.3 shows how the standard 555 can be configured as an astable pulse generator.

In order to understand how this circuit operates, assume that the output (pin 3) is initially high and that the internal transistor TR1 (see Fig.2) is in the non-conducting state. The capacitor, *C*, will begin to charge with current supplied by means of series resistors, R1 and R2.

When the voltage at the threshold input (pin 6) exceeds two thirds of the supply voltage, the output of the upper comparator, IC1, will change state and the bistable (IC3) will become reset due to voltage transition that appears at the R input to IC3. This, in turn, will make the inverted output (marked $\overline{Q}$ in Fig.2) go high, turning TR1 on and saturating it at the same time. Due to the inverting action of the buffer, IC4, the final output (pin 3) will go low.

The capacitor, *C*, will now discharge, with current flowing through R2 into the collector of TR1. At a certain point, the voltage appearing at the trigger input (pin 2) will have fallen back to one third of the supply voltage, at which point the lower comparator (IC2) will change state and the voltage transition at S (Fig.2) will return the bistable to its original set condition. The inverted $\overline{Q}$

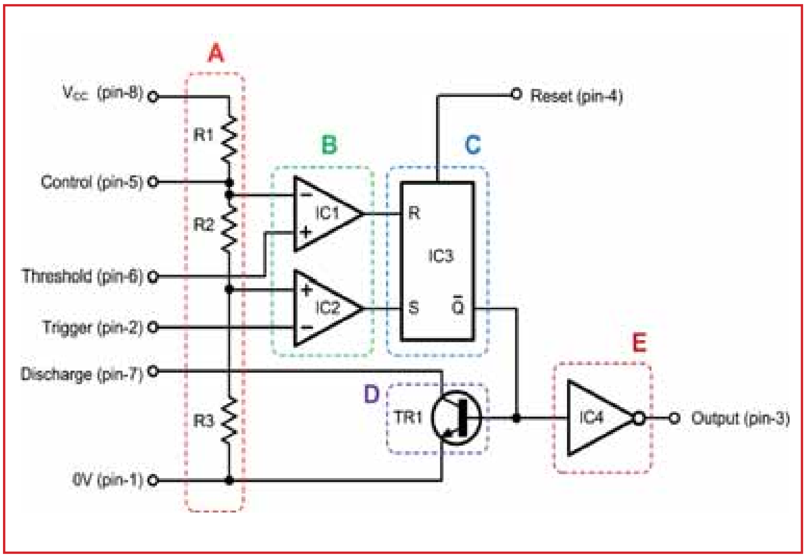


Fig.2. Simplified internal arrangement of a standard 555 timer

Table 1: Main features of the 555 timer IC

Feature	*Function*
A	A potential divider comprising R1, R2 and R3 connected in series. Since all three resistors have the same values the input voltage (V_{CC}) will be divided into thirds, i.e. one third of V_{CC} will appear at the junction of R2 and R3 while two thirds of V_{CC} will appear at the junction of R1 and R2.
B	Two operational amplifiers connected as comparators. The operational amplifiers are used to examine the voltages at the ***threshold*** and ***trigger*** inputs and compare these with the fixed voltages from the potential divider (two thirds and one third of V_{CC} respectively).
C	An R-S bistable stage. This stage can be either **set** or **reset** depending upon the output from the comparator stage. An external reset input is also provided.
D	An open-collector transistor switch. This stage is used to discharge an external capacitor by effectively shorting it out whenever the base of the transistor is driven positive.
E	An inverting power amplifier. This stage is capable of sourcing and sinking enough current (well over 100mA in the case of a standard 555 device) to drive a small relay or another low-resistance load connected to the output.

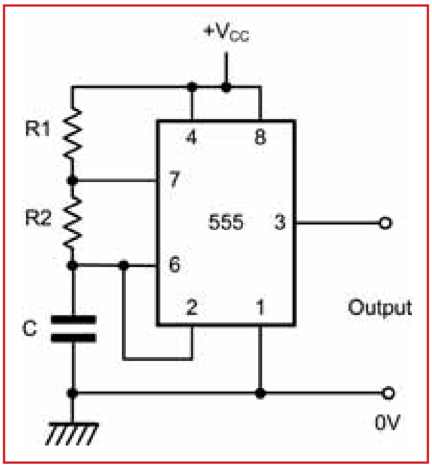


Fig.3. Circuit configuration for a 555 astable

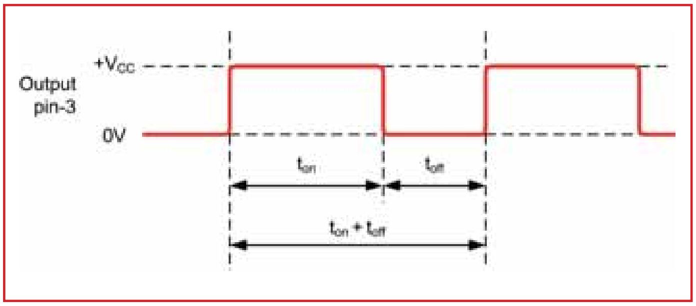


Fig.4. Waveforms for astable 555 timer operation

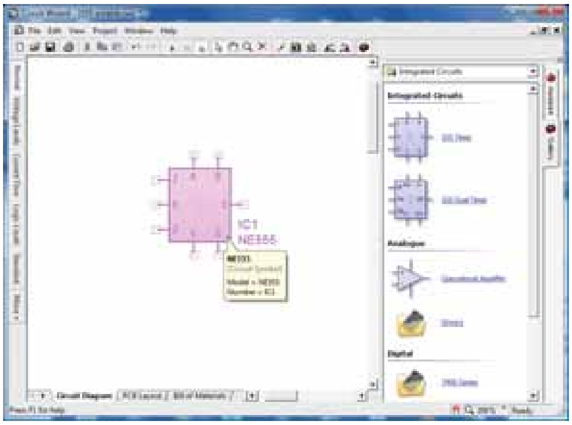


Fig.5. The 555 is available from the integrated circuits folder within Circuit Wizard's gallery of components

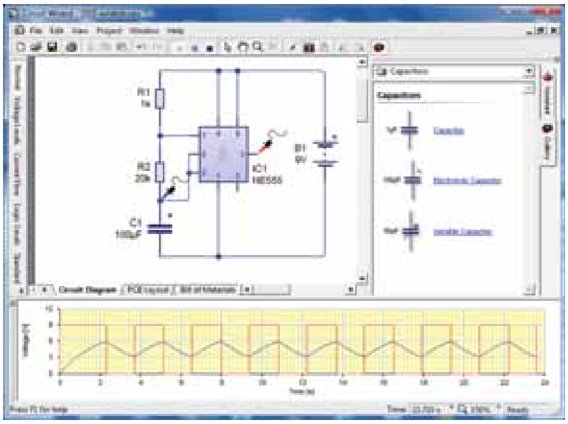


Fig.6. Using Circuit Wizard to test a 555 astable oscillator

output then goes low, TR1 switches off (no longer conducting), and the output (pin 3) goes high. Thereafter, the entire charge/discharge cycle is repeated indefinitely.

The output waveform produced by the circuit of Fig.3 is shown in Fig.4. The waveform has the following properties:

Time for which output is high:

$$t_{on} = 0.693\ C\ (R1 + R2)$$

Time for which output is low:

$$t_{off} = 0.693\ C\ R2$$

Period of output waveform:

$$t = t_{on} + t_{off} = 0.693\ C\ (R1 + 2R2)$$

Pulse repetition frequency:

$$p.r.f. = \frac{1.44}{C(R1+2R2)}$$

Mark-to-space ratio:

$$\frac{t_{on}}{t_{off}} = \frac{R1+R2}{R2}$$

Duty cycle:

$$\frac{t_{on}}{t_{on}+t_{off}} = \frac{R1+R2}{R1+2R2} \times 100\%$$

Once again, note that where t is in seconds, C is in farads, R1 and R2 are in ohms.

Get real

The circuit that we have just met can both be simulated and tested easily using Circuit Wizard. As always, this will allow you to experiment with component values and make some small 'tweaks' to a circuit before you finally commit to a printed circuit board layout. We shall briefly describe the process that we used in the next few paragraphs.

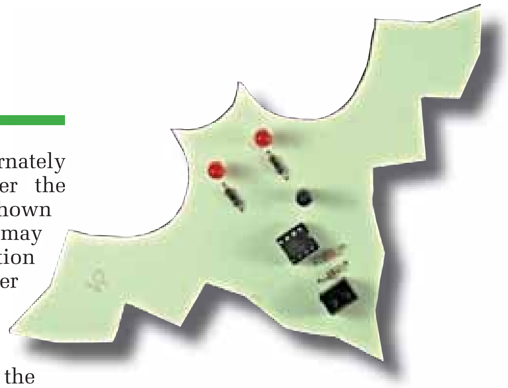
The 555 astable circuit that we met earlier can be easily tested in Circuit Wizard. This provides you with an excellent opportunity to check and optimise component values without having to use any real components. The 555 device can be found in the Integrated Circuits folder in Wizard's Gallery of parts, as shown in Fig.5.

Once again, it is important to be able to view the waveforms within the circuit under test and Circuit Wizard will let you do this with ease, as shown in Fig.6. Here we are displaying two waveforms; the voltage present at the trigger/threshold inputs (pin2 and pin 6), and the voltage present at the output (pin3). You can get a good idea of how the circuit operates by observing these waveforms and changing the values of R1, R2 and C1. In particular it is worth noting how the voltage dropped across C1 (the blue waveform in Fig.6) varies between 1/3 and 2/3 of the supply voltage as the capacitor is being alternately charged and then discharged. Using the formulae that we mentioned earlier you can easily design an astable oscillator that will produce a waveform with a wide range of 'on' and 'off' times.

A note regarding Circuit Wizard versions:

Circuit Wizard is available in several variants; Standard, Professional and Education (available to educational institutions only). Please note that the component library, virtual instruments and features available do differ for each variant, as do the licensing limitations. Therefore, you should check which is relevant to you before purchase. During the Jump Start *series we aim to use circuits/features of the software that are compatible with the latest versions of all variants of the software. However, we cannot guarantee that all items will be operational with every variant/version.*

Crazy Eyes – using Circuit Wizard



AS WITH all of our *Jump Start* circuits, we've given you the underpinning theory, putting it into practice using circuit simulation and converting it to a PCB design. The Circuit Wizard software that we've used throughout the series makes this process really simple and great fun, and we always recommend following the tutorials to enter the circuits and converting them to your very own PCB designs.

However, if this isn't your bag, you can simply use our artwork to prepare your boards or download our own Circuit Wizard files from the *Jump Start* website at: **www.tooley.co.uk/epe** – Don't forget, if you'd just prefer a pre-made PCB, you can purchase these from the *EPE PCB Service* (see page 78).

Circuit Wizard

Now we're going to put some of the 555 timer theory we've just learnt to use with our two Halloween-themed circuits. Our first circuit is a basic 555 astable circuit that drives a pair of LED 'Crazy Eyes' that will flash alternately several times a second. Enter the circuit in to Circuit Wizard as shown in Fig.7 and give it a try. You may like to slow down the simulation speed (right click the timer display on the bottom bar of the screen when running and select a lower time interval) to really see what's going on in the circuit and/or check out the Current Flow view (left hand bar).

Output monitoring

A neat way to monitor the output of the 555 is to add a probe to the output pin of the chip (pin 3). This should automatically bring up the graph pane at the bottom of the screen allowing you to see how the output operates over time, as shown in Fig.8.

You may need to adjust the time and/or voltage axes of the graph to achieve a clear trace and you will need to reduce the simulation speed. You should see that the output is toggled on/off around six to seven times a second producing a square wave pattern, as shown in Fig.9. Try experimenting with different values for R1, R2 and C1 and note the effect it has on the output.

Notice how we've used two LEDs connected to the output pin of the 555 (pin 3). When the output is low, there will be 9V across D1 and its series resistor R3 and current will flow through the LED into pin 3, as shown in Fig.10. This is known as 'sinking'. Conversely when the output is high, current will flow from the output pin down through D2, known as 'sourcing', as shown in Fig.11.

It's worth noting that when working with integrated circuits, the manufacturer will state a maximum current that the chip can sink or source to/from a pin and they often differ. Therefore, this can influence how output devices are connected when a circuit is designed.

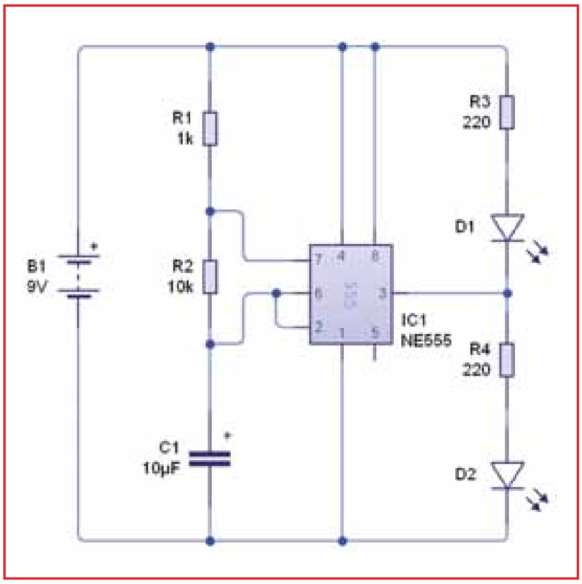


Fig.7. 'Spooky' Crazy Eyes circuit diagram, realised using Circuit Wizard

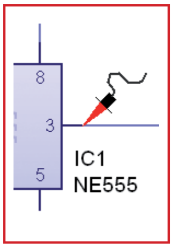


Fig.8. Adding a probe to monitor the 555 output pin (3)

You will need...

Crazy Eyes

1 PCB, code 872, available from the *EPE PCB Service*, size (basic rectangular board) 31mm × 71mm
1 Two-way PCB mounting terminal block
1 9V (PP3) battery, with clip and leads
1 8-pin low-profile DIL socket

Semiconductors
2 red 5mm LED (D1 and D2)
1 555 timer (IC1)

Capacitors
1 10µF (C1)

Resistors
1 1kΩ (R1)
1 10kΩ (R2)
2 220Ω (R3 and R4)

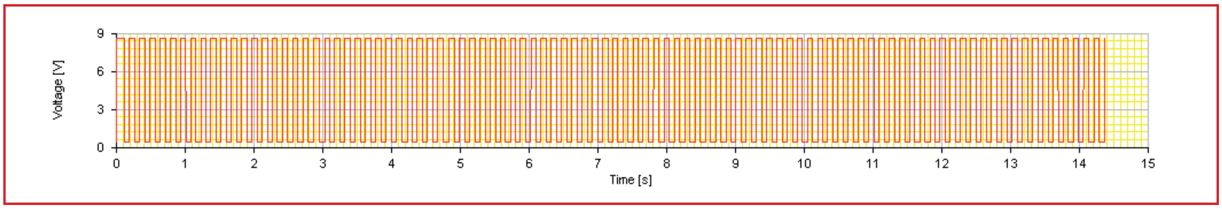


Fig.9. 555 output waveform displayed by Circuit Wizard

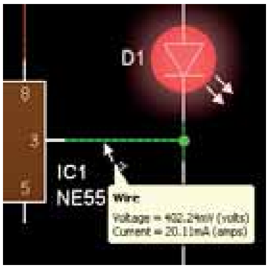


Fig.10. The 555 sinking an output current

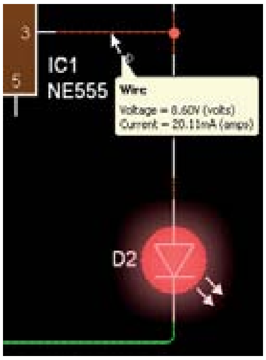


Fig.11. The 555 sourcing an output current

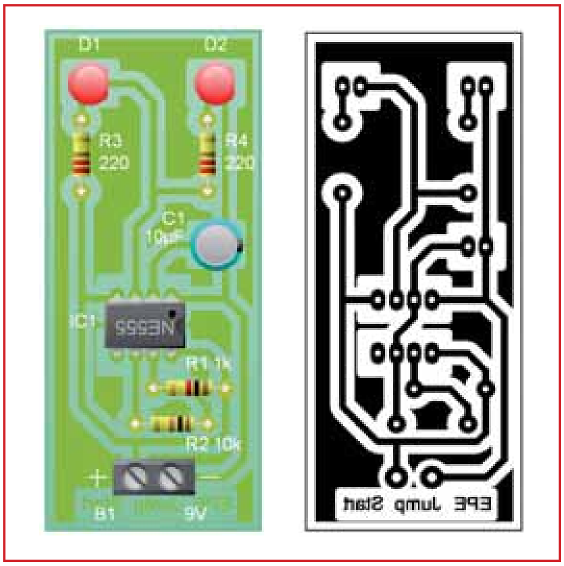


Fig.12. Rectangular Crazy Eyes component layout and PCB artwork

Creating a circuit board

Now we're happy with the design and operation of the circuit, we can move on to creating a PCB. We've given you a few examples of the kinds of things that you could do with this circuit. Fig.12 shows the circuit as a basic rectangular PCB.

This would be ideal for placing behind a gruesome picture/photo, or the cutout of a Halloween-themed shape. Equally, it could easily be hidden in a scary toy/model or mask. As a further customisation, when converting to a PCB, the PCB-mounted LEDs could be exchanged for two-pin screw terminals so that they could be mounted more freely. You can purchase a pre-made rectangular PCB from the *EPE PCB service,* code 872.

Halloween PCBs

A neat way to create a Halloween decoration using the PCB itself is to manufacture the board in to a suitable shape. Fig.13(a) and Fig.13(b) show our two sample PCB designs, in the form of a ghost and a bat respectively.

To change the shape of the PCB you will first need to change the standard rectangular circuit board shape into a polygon, as shown in Fig.14(a). After this you can easily add extra nodes (corners) to the shape by holding down the Ctrl key and left clicking on an edge. You can then drag the nodes (shown as small black squares) to form the desired shape, as shown in Fig.14(b).

Once you've etched your PCB, you can then cut and file your PCB into shape using your lines as a guide. Take care when doing this, as PCBs can be brittle. Before drilling/assembly you could also decorate the topside of the PCB. For example, spray paint or permanent markers could be used to add some colour/detail.

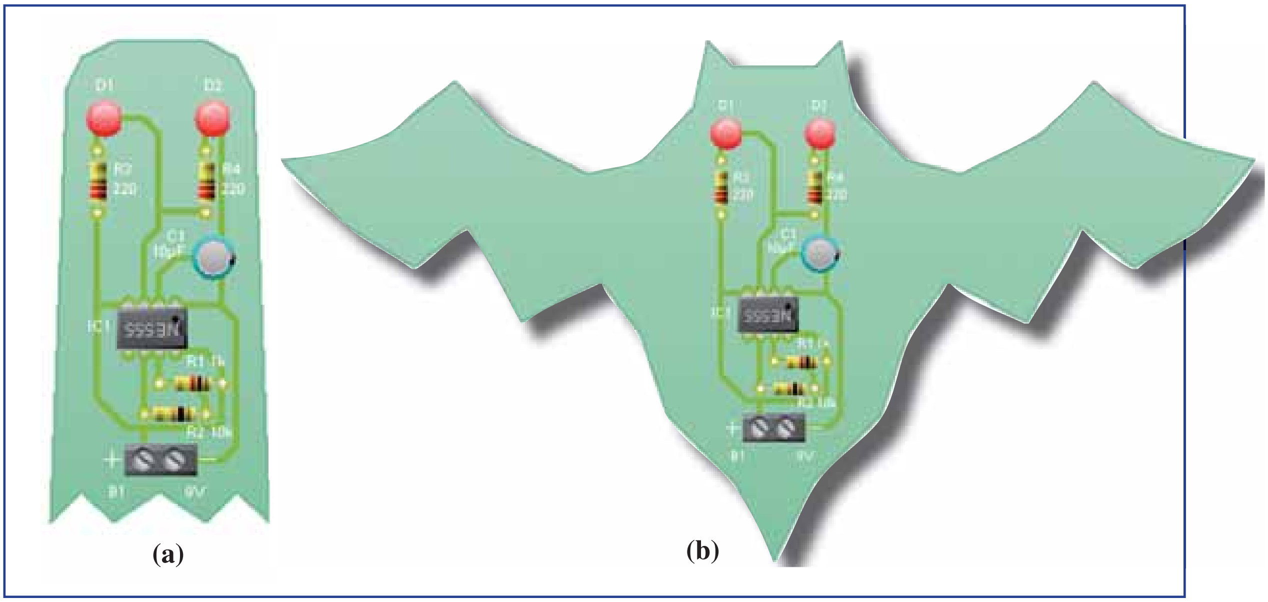


Fig.13. Our two sample Halloween-themed PCB designs

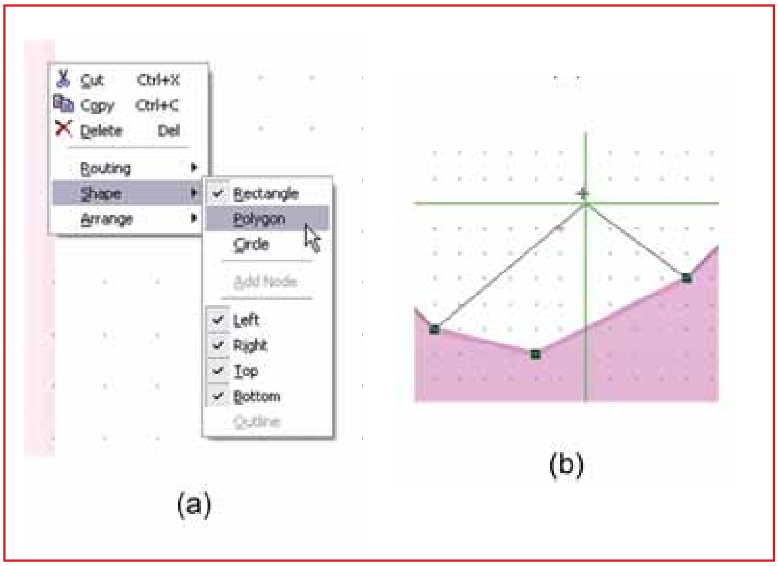


Fig.14. (a) Converting the circuit board to a polygon shape, (b) moving nodes to create the desired shape

For more info:
www.tooley.co.uk/epe

Ghostly Sound Generator – using Circuit Wizard

OUR SECOND 555-based circuit creates a ghostly warbling sound that's sure to chill you to the bone or just annoy anyone that has to listen to it for any length of time! The circuit makes use of two 555 ICs, and is shown in Fig.15.

The first 555 (IC1) effectively controls the modulation of the second 555 to alter the frequency of the audible signal it generates, creating a siren-like sound (in fact the circuit could easily be modified for this purpose too). The second 555 (IC2) drives a small 8Ω loudspeaker directly. A second transistor could be used here should you wish to amplify the signal to drive a larger speaker.

You will need...

Ghostly Sound Generator

1 PCB, code 873, available from the *EPE PCB Service*, size (basic rectangular board) 48mm × 61mm
1 miniature 8 ohm loudspeaker
2 2-way PCB mounting screw terminal blocks
1 9V (PP3) battery, with clip and leads
2 8-pin low-profile DIL sockets

Semiconductors
1 BC557 *PNP* transistor (Q1)
2 555 timers (IC1 and IC2)

Resistors
2 10kΩ (R1 and R5)
2 100kΩ (R2 and R6)
1 1kΩ (R4)
1 4.7kΩ (R3)
1 100Ω (R7)

Capacitors
1 22µF radial elect (C1)
1 10nF ceramic (C2)
1 100µF radial elect (C3)

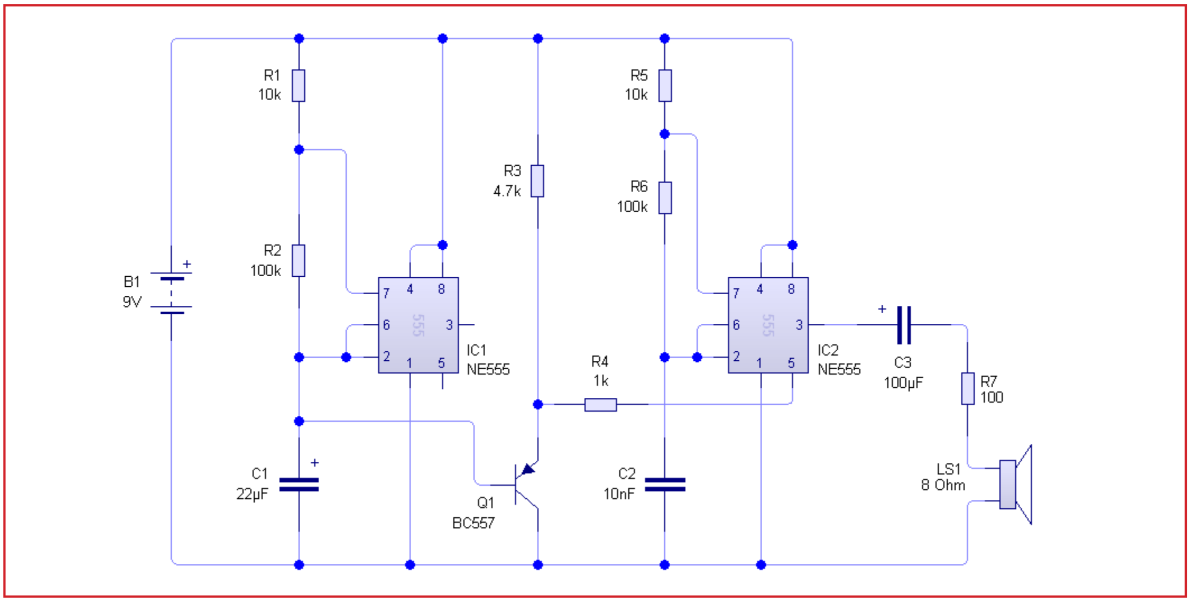


Fig.15. Finalised circuit diagram for the *Ghostly Sound Generator*, displayed using Circuit Wizard

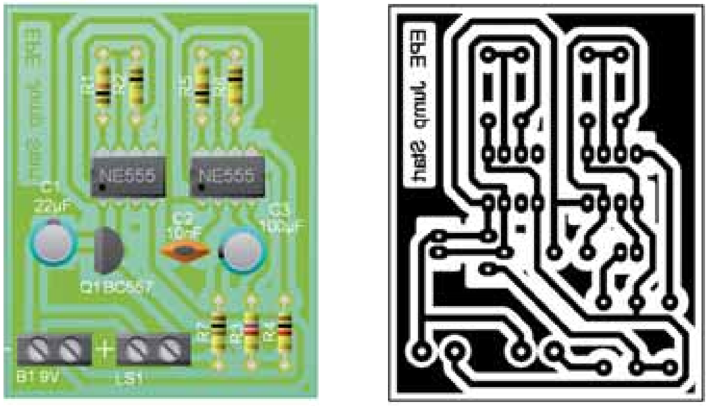


Fig.16. Standard PCB component layout and PCB artwork

If you are using Circuit Wizard Professional or Education, you could substitute the two 555s for a single 556 dual IC chip (this component model is not included in the Standard version of the software and therefore we have used individual ICs to ensure compatibility with the two different versions).

Next month

In preparation for the winter months, in next month's *Jump Start* we will be developing a Frost Alarm, ideal for use by motorists and gardeners.

Photo gallery...

Here are some photos of our prototype circuits, but we're sure that you can do better – try to use your imagination to create some really awesome and scary Halloween circuits!

In an educational context, learners should be encouraged to realise their own designs, ending up with a finished project that demonstrates their competence, skills and understanding.

As with all of the *Jump Start* series, the underpinning theory and our example designs are intended to provide the starting point for your own learning and creativity.

Flashing bat's eyes

Flashing eyes circuits

Ghostly sound generator

Special thanks to Chichester College *for the use of their facilities when preparing the featured circuits.*

EPE EXCLUSIVE

Win a Microchip dsPICDEM SMPS Buck Board

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Key features of the dsPICDEM SMPS Buck Development Board include: • Socketed dsPIC30F2020 on board connected to power devices and circuitry for controlling dual independent low power DC-to-DC synchronous buck converter circuits • Buck converters can operate in synchronous or asynchronous modes • Input voltage range 7V to 15V (nominal 9V) • User can enable a dynamic output load to investigate transient response • User potentiometers to simulate application features, such as voltage trim, remote voltage sense, voltage tracking, current sharing • MPLAB ICD 2 or REAL ICE support ready • RS-232 serial channel • Example software for implementing digital dual synchronous buck converter

Package Contents: • dsPICDEM SMPS Buck Development Board • Example software, educational material, and documentation on CD

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Our regular round-up of readers' own circuits

WIN A PICO USB DrDAQ DATA LOGGER PH KIT WORTH £139

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If you have a novel circuit idea which would be of use to other readers, then a Pico Technology USB DrDAQ Data Logger PH Kit could be yours. After every 20 published IU circuits, the best entry will be awarded a USB DrDAQ Data Logger PH Kit worth £139. In addition, a runner up will be awarded with a USB Dr DAQ Data Logger woth £99.

Simple GSM Alarm System – *On call*

THIS alarm system calls the owner's mobile phone when an alarm event occurs. You will be notified within seconds of an alarm occurring, through a call to your mobile phone. It is built into the housing of a discarded computer hard disk (HDD). The advantage of this is it uses a ready-made strong metal box.

The HDD's motor is used as a sensitive transducer. The basic system consists of a detector, counter, mobile phone and associated parts.

Operation

Referring to the circuit diagram, Fig.1, even the slightest motion of the rotor of the HDD's motor generates a voltage in the stator coil (oscillations appear). These voltage oscillations are fed to the comparator IC1 (LM311), which acts as an amplifier. In other words, this sub-system is a magnetic motion transducer – it detects rotation of the HDD rotor. LED1 flashes when any HDD rotor motion occurs, it serves as a light indicator.

In this circuit, a low-level impulse will send IC2a's output high and this voltage is applied to the base (b) of *NPN* transistor TR1, switching it on. Capacitor C3 charges up via transistor TR1 and discharges via resistor R5, with a time constant of about 20s.

This allows the oscillator (based on IC2b, IC2c, C4, R6) to operate by pulling pin 5 of IC2b high. This sends a pulse to the clock (pin 14) of counter IC3, where the pulses are duly counted.

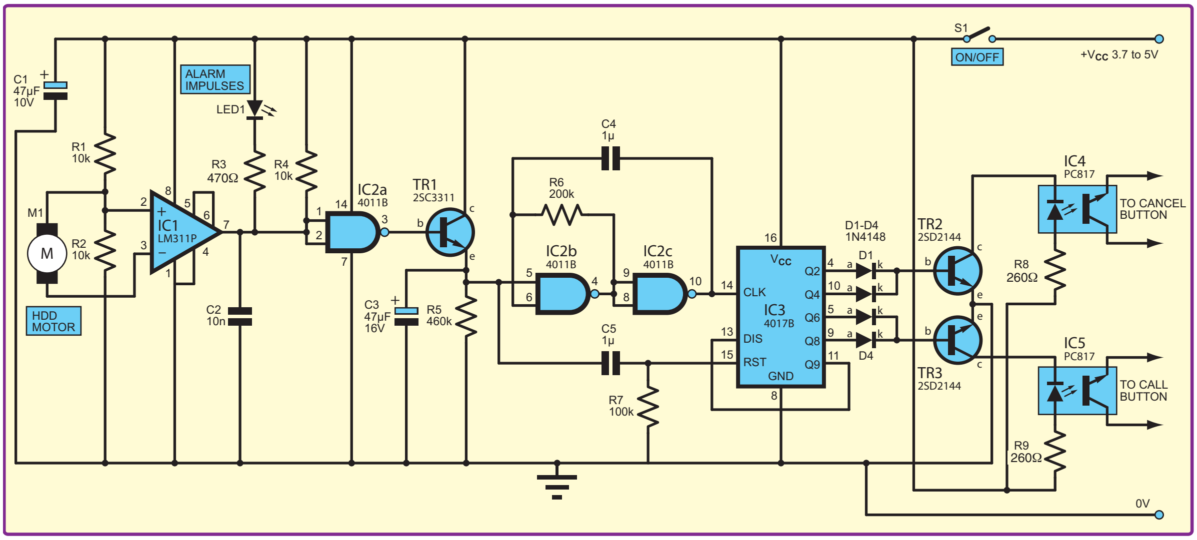

Fig.1. Circuit diagram for the Simple GSM Alarm System

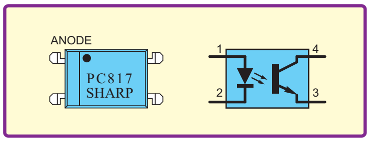

Fig.2. Optocoupler pinout details

Two impulses (from IC3 pin 4 and pin 10) via diodes D1 and D2 turn on transistor TR2, which ‘presses’ the ‘cancel’ button via optocoupler IC4. This is necessary to reset all random and non-random calls, as well incoming SMS.

Then, in the same way, transistor TR3 is turned on via diodes D3, D4 (impulses from IC3 pin 5 and pin 9). This mimics ‘pressing’ the ‘call’ button via optocoupler IC5. The call to the last dialled number will be made after about five seconds.

Having counted to ten, the counter stops when pin 13 goes high. After a period of about 15s to 20s, capacitor C3 has discharged enough to stop the alarm process, and our system is ready for another alarm call.

Construction tips

The device is built on a single-sided PCB. I have not specified a particular PCB design because the size and shape of the board depends on the size and free internal space of whichever HDD you use.

As discussed earlier, the sensor is the HDD’s motor. These typically have three pins, and the outer two are usually the ones to use. You may need to experiment with your chosen HDD to find the connections that supply an output.

For the phone, any GSM system should suit, but obviously you need one which actually uses buttons and not a touch screen. Carefully solder the leads of the buttons ‘call’ and ‘cancel’, as well as the phone’s battery’s pins (+ and –) to power the alarm system itself.

Before use, you should call the target phone number to be used when an ‘alarm call’ needs to be made and then set the phone to redial.

The unit is powered from the phone’s battery (3.7V), although it should work up to 5V. The current consumption from the battery in ‘stand by’ is typically around 1-3mA.

Set up

It’s necessary to fasten the detector securely for maximum sensitivity, that is ensure motion isn’t damped.

Semiconductors

A few comments on components: IC1 can be LM311P or LM211. The

diodes can be 1N4148 or 1N414. The LED should be a low-current type. C1 and C3 should be electrolytic, and C4 and C5 should be non-polarised, for example polyester. The resistors are all 0.125W.

Alexey Uskov, Vladivostok, Russia

RF Detector probe for multimeter – *Check it out*

THIS circuit (Fig.3) is a simple amplified RF detector for use with a multimeter. It was built because I was having trouble with an audio amplifier that was becoming unstable. It turned out that the LM386 chip was radiating enthusiastically in the shortwave band (my fault!).

The detector works up to around 150MHz, which is more than is really needed for non-radio work. It is capable of checking crystal clocks, amplifier instability and radio control transmitters. It can also detect radiation from digital circuits and switch-mode power supplies. It is not intended for radio hams, who often have their own RF detectors, but is meant for the general experimenter who doesn’t work with RF, but who may need to detect it occasionally.

The circuit draws power from a digital multimeter set to one of its resistance ranges. Choose a resistance range that reads near full-scale when there is no RF. As the RF increases, the display reading will reduce. You can also use an analogue multimeter, but remember that the test leads have the ‘wrong’ polarity and the resistance scale reads ‘the other way round’.

Unlike most RF detectors, this one uses a probe with a small copper or brass plate, about 1cm by 2cm, soldered to the end. This plate is pushed right down close to circuitry, PCB tracks or components. It doesn’t make contact, in fact it is completely insulated to prevent nasty accidents. The RF voltage is coupled capacitively into the base of the transistor and the user’s hand-capacitance provides the ground return.

I suppose we shouldn’t be using obsolete components like germanium transistors, but in this case, the low Vbe of germanium allows the detector to run off as little as 0.5V, which is what most modern DMMs supply on their resistance ranges. Another nice feature of germanium is the way we can use a diode to temperature-stabilise the base bias. The AF139 is still available at reasonable prices from specialist suppliers. Equivalents are VHF/UHF parts like AF239, 2SA422, or you might salvage a suitable transistor from an old TV tuner.

Walter Gray, Farnborough, Hampshire

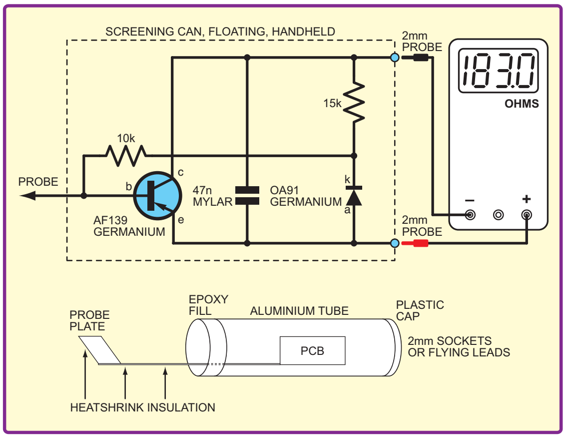

Fig.1. Circuit diagram for the RF Detector Probe for Multimeter

CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

Real ADCs continued

THIS month we continue the theme of analogue-to-digital converter (ADC) specifications which we started last month in response to a question posted on *Chat Zone* by **echase**.

How much IC-to-IC error is there on the A/D's on 8-bit PICs? I need the error to be within 1 LSB at the midpoint of a 10-bit sample ie, with a voltage derived from the midpoint of the supply rail one PIC reads 512 because I have a trimpot calibrated to the middle of the 512 step. If I change the PIC will the new one always still read 512 without my having to adjust the trimpot? Based on a sample of only two I got them both to read the same.

For one PIC, the datasheet quotes integral error, differential error, offset error and gain error all at ±1 bit. Added together, that is four bits of error, but in reality I guess you don't get them all worst case. To get my required accuracy I guess I really need ±½ bit.

Last time, we looked at quantisation error, which is inherent in all ADCs and at the non-ideal characteristics mentioned by echase such as offset, gain error and integral and differential nonlinearity (INL and DNL). This month, we look at some of the time-related characteristics of ADCs, in particular, in relation to the sample and hold process which is required as part of most conversion circuits. We will see that these characteristics also influence conversion accuracy.

Conversion time

The most obvious ADC timing specifications are the conversion time and sample rate. Conversion time t_C, is how long it takes from a conversion being initiated and the data becoming available. If conversions are performed continuously, the sample rate indicates the number of conversions per second that can be performed.

In the simplest case, sample rate will be $1/t_C$, but it is not always that simple. Some converters (eg, pipelined ADCs) have a faster sample rate than $1/t_C$ because processing of multiple conversions occurs simultaneously. In such cases, there is a latency of several conversion cycles before the result of a particular conversion is available.

In order for an ADC to perform a conversion it needs the analogue input voltage to be constant for a certain amount of time, which will depend on the implementation of the ADC. If the input voltage changes significantly during this time, then errors may occur in the conversion. If the input signal changes very slowly with respect to the ADC's operating speed, the voltage change may not be significant and it may not be necessary to take any special action – the input signal can then be connected directly to the conversion circuit.

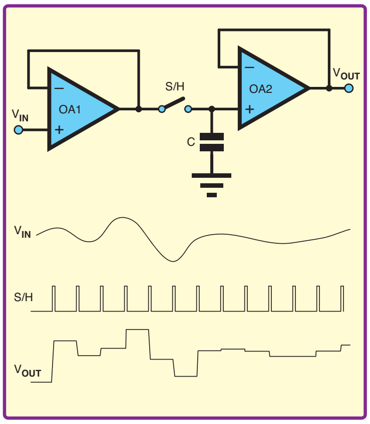

Fig.1. Basic sample and hold circuit

In many ADC applications, expected changes in the input voltage will result in errors if there is a direct connection of the signal to the conversion circuitry. In such cases, a sample and hold (or track and hold) circuit is required between the input signal and converter to hold the voltage to be converted steady during the conversion.

For example, a successive approximation converter (a common type of ADC) uses an internal digital-to-analogue converter (DAC) to compare an analogue version of the digital output code with the input voltage. As the name suggests, it improves the accuracy of the digital code in successive steps using the comparison to decide on each output bit in turn from most to least significant. If the input voltage changes during the conversion, then the partially complete digital code will no longer relate to the input value, causing errors in the final result.

Sample and hold

A basic sample and hold circuit is shown in Fig.1. In many cases the sample and hold circuit will be included on the ADC chip (or as part of a microcontroller's ADC subsystem) so you do not have to worry too much about the circuit design. However, separate sample and hold chips are available. The performance of a typical ADC will depend on the characteristics of the built-in sampling circuit and therefore it helps to be aware of the process when reading ADC specifications.

A graph of input voltage to a converter against time (for which there is no sample and hold), is shown in Fig.2. We assume the conversion takes a certain time, t_C, (the conversion time) during which the input changes from V_1 to V_2. If this change (V_2-V_1) is larger than one LSB (least significant bit) then the conversion may be disrupted. An LSB is the input voltage difference between adjacent digital output codes, which we discussed in more detail last month.

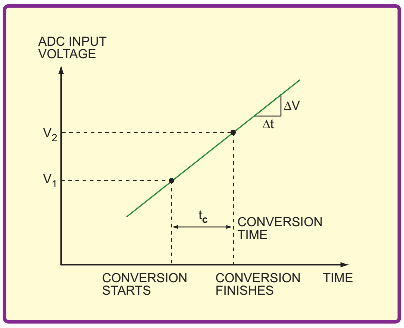

Fig.2. Changing input signal to an ADC

Rate of change

For a changing input voltage, the possibility of error depends on the relationship between the rate of change of voltage and the conversion time. The rate of change of input voltage is the voltage difference

ΔV divided by the time taken for that change Δt (ie, rate = $\Delta V / \Delta t$), as shown on Fig.2. The symbol Δ (delta) means 'change of'. Measuring the rate as show on Fig.2 is fine for a constant rate of change, but for real signals, where the rate changes constantly, we use the calculus form: rate = dV/dt, which simply implies measurement of the rate over an infinitely short time interval.

If we multiply the rate of change by the conversion time we can find by how much the input signal changes during this time. As already noted, the change in signal voltage during the conversion time must be less than the LSB to prevent errors. This applies for both one-off conversions and conversion at a constant sample rate. We can write this mathematically as:

$$t_c \frac{dv_{in}}{dt} \le LSB \,.$$

If this condition is not satisfied, we have to use a sample and hold circuit. Last month we saw that:

$$LSB = \frac{range}{2^N} \,,$$

where the ADC's input range is defined as $V_{RefH} - V_{RefL}$, the difference between the upper and lower reference voltages. N is the number of bits.

For example, consider a 10-bit ADC with a conversion time of 1μs – is a sample and hold required for an input signal of amplitude 5V and maximum rate of change of 20Vms^{-1}?

We calculate:

$$t_c \frac{dv_{in}}{dt} = 10^{-6} \times 2 \times 10^4 = 2 \times 10^{-2} V$$

$$\frac{v_{in}}{2^N} = \frac{5}{2^{10}} = 4.88 \times 10^{-3} V \,.$$

The inequality above is not satisfied (ie, 2×10^{-2} is not less than 4.88×10^{-3}) so a sample and hold is required.

An obvious question at this point is how we know what rate of change value to use. We should probably look at the most demanding case and one way to do this to consider a sine wave at the highest frequency we are processing.

Our input can be written:

$$v_{in} = A \sin(2\pi f t) \,,$$

where f is the frequency in hertz and A is the amplitude (peak). To find the rate of change we use calculus to differentiate the signal function (find dv_{in}/dt). Readers familiar with calculus will know that differentiating a sine function gives a cosine function, otherwise just take our word for it. We get:

$$\frac{dv_{in}}{dt} = 2\pi f A \cos(2\pi f t)$$

The maximum value of a cosine function is 1, so the maximum rate of change is $2\pi f A$. We can use this figure in the calculation given above to determine if a sample and hold is required. The same approach can also be used with other converter timing issues, as we shall see later.

Returning to Fig.1, we can see that the sample and hold comprises two unity-gain buffer amplifiers, an electronically controlled switch (typically a MOSFET) and a capacitor. Fig.3 shows the detail of the waveforms around a single sampling cycle of a sample and hold circuit, from which we identify a number of characteristics associated with sample and hold circuits and consequently the ADC chips which include them.

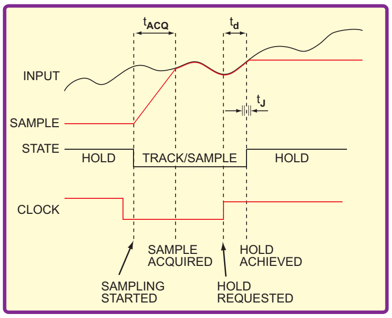

Fig.3. Sample and hold timing characteristics

The sampling switch is controlled by the sampling clock, which instructs the sample and hold to change between the sample (track) and hold states. When the switch is closed, sampling begins and the capacitor will charge to the input voltage, this takes a finite time – the time required by the sample and hold to acquire the sample value. The more accurately you need the capacitor voltage to match the input voltage, the longer you have to wait (all other things being equal).

Once the capacitor voltage has become effectively equal to the input voltage it will continue to change with the input voltage – it tracks the input voltage, hence the term 'track and hold' is used for this type of circuit as well as sample and hold.

More formally, we can define 'acquisition time', t_{ACQ}, as the duration from the end of the hold state (sampling begins) and the point at which the voltage on the sampling capacitor settles to within 1 LSB of the input voltage. Acquisition time is given by:

$$t_{ACQ} = \ln(2^N) R_{source} C_{sample}$$

where R_{source} is the source impedance (eg, input buffer's amplifier output impedance, if one is used), C_{sample} is the sampling capacitance, and N is the number of ADC bits.

Once the input voltage has been acquired, the sample and hold circuit can enter the hold state to allow conversion to take place. Again, this is controlled by the sampling clock. The relevant clock edge represents the time at which the command to hold is given. The circuit will take a finite time to actually enter the hold state (and hence take the sample). This is called the 'aperture delay', t_{AD}.

In the hold state, the sample capacitor holds the voltage present at the sample time, or at least that is what would happen in an ideal circuit. In reality, imperfections in the capacitor, and the fact that the second buffer does not have infinite input impedance, mean that the capacitor's charge will leak away resulting in a progressive droop in the held voltage.

We define 'droop rate' as the rate at which voltage on sample capacitor changes during the hold interval. It is determined by I_L/C_{sample} where I_L is the leakage current and C_{sample} is the sampling capacitance. The droop should be less than ½ LSB during the conversion time.

Many systems in which ADCs are used have a constant frequency sample clock, (eg, digital audio or video), rather than taking samples at arbitrary times (eg, one-off measurements controlled by a user). In such cases, variations in the 'aperture delay' between clock cycles will cause a change in effective sample time. Variation in the 'aperture delay' is referred to as 'aperture jitter', t_J. Variation in clock edge timing (clock jitter) will also have the same effect, but the clock is often external to the ADC, so this is typically a system parameter rather than ADC characteristics.

Aperture jitter

Sampling at the wrong time point means that the wrong voltage will be recorded. The voltage deviation resulting from aperture jitter will show up as noise in the sampled signal. The problem gets worse for higher input signal frequencies because the signal voltage will change more in the jitter time. Thus aperture jitter is a critical characteristic in ADCs used for high frequency signals

In order for the aperture jitter of the sample and hold not to cause conversion errors, the change in signal voltage, V_{in}, during the jitter time, t_J, must be less than the quantisation error. This is similar to the problem discussed earlier about the need for sample and hold, except

now we used aperture jitter rather than conversion time. So we need:

$$\frac{dV_{in}}{dt} t_J < \frac{range}{2^N}$$

For a sinewave with a peak value A equal to half the ADC range (so the peak-to-peak sine wave covers the entire input range, ie, range = $2A$) we have, using the maximum rate of change of sinewave calculated above,

$$2A\pi f t_J < \frac{2A}{2^N},$$

so

$$t_J < \frac{1}{2^N \pi f}.$$

For example, CD audio uses 16 bits at a sample rate of 44.1kHz. This means the highest input frequency must be limited to 22.05KHz (if we a have perfect anti-aliasing filter). This is a requirement of sampling theory – the highest frequency present in the input must be less than half the sampling frequency otherwise errors (known as aliasing) will occur in the sampled data.

The above formula indicates a maximum aperture jitter of 220ps and illustrates that aperture jitter requirements can be quite demanding. A sample rate of 44.1 kHz is around one sample every 23μs – about one hundred thousand times longer than the indicated maximum aperture jitter time. However, the above calculation is probably somewhat pessimistic about the aperture jitter requirements as most of the content of a real audio signal will be at lower frequencies.

INTERFACE

By Robert Penfold

Simple optical interfacing

IN recent years, the *Interface* articles have tended to be dominated by programming languages, USB ports, and input/output lines. However, there is a lot more to interfacing than this, and real world interfacing often requires what could be termed 'pure' electronics. In other words, the type of thing that formed the staple diet of computing magazines in the pre-computer era. In some cases, the electronics involved is more analogue than digital, and that is certainly the case this time.

It is sometimes necessary for a computer system to detect the presence (or otherwise) of a person or an object of some kind. Applications such as intruder detectors, lap timers, and other types of timing require the electronics to know when something or someone reaches a certain point or crosses a line.

There are numerous ways of handling this type of thing, and the best approach depends on the particular application. A magnet and a Hall effect sensor are fine for some applications, such as RPM meters, but with a range of a few millimetres they are unlikely to be of much use for detecting a competitor as they cross the finishing line.

Long and short of it

Optical detectors in their various forms can be used in a wide range of both short and longer-range applications. For short-range operation, a sensor of this type can be very simple indeed, but for use at longer ranges, it is necessary to resort to pulsed systems that require slightly more involved circuitry, but which, by modern standards, are still quite straightforward. A simple DC optical sensor can be as basic as the one shown in the circuit diagram of Fig.1.

This has phototransistor TR1 as the sensing element, and operation of the circuit relies on the fact that its leakage level depends on the light level received. In total darkness TR1 is effectively an ordinary silicon transistor, and it has the very low collector-to-emitter leakage current normally associated with a device of this type. The actual leakage current is typically a few nanoamps and is totally insignificant.

Transistor TR2 operates as a common-emitter switch, and under these conditions it receives no base (b) current and

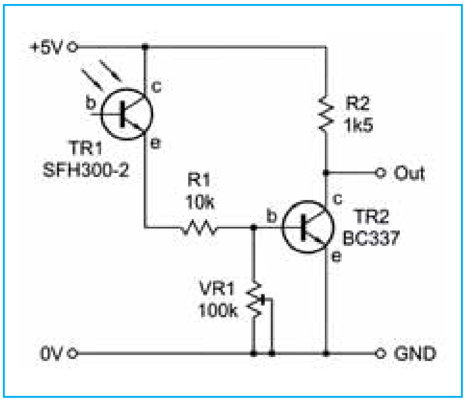

Fig.1. A simple optical detector circuit that produces a low output level when a strong enough light level is received. TR1 can be practically any phototransistor for visible light applications

is switched off. Resistor R2, therefore, pulls the output high (logic 1).

Its leakage level increases when TR1 is subjected to light, and the higher the light level, the greater the leakage current. If the light and leakage levels are high enough, TR2 will receive sufficient base current to bias it into conduction, and the output will go low (logic 0). Variable trimpot 'resistor' VR1 diverts some of the base current, and it acts as a preset sensitivity control.

An SFH300-2 is specified for TR1, but the circuit should work with practically any phototransistor. However, bear in mind that some of these devices have a built-in filter and will only respond significantly to 'light' at the shorter end of the infrared spectrum. This can be advantageous if the detector is used in conjunction with a suitable infrared light source, since it will not be affected very much by the ambient light level, but the circuit would not work to a usable degree as a visible light sensor.

Seeing the light

There are various ways of using a detector of this type. In most cases, the phototransistor is fitted where it will receive sufficient light to send the output low under standby conditions. Ambient light and a suitable setting for preset VR1 will often be enough to achieve this, but in some cases a light source aimed at the sensor will be required.

For something like timing and lap counting for a slot car circuit, the sensor could be mounted under the track, 'looking' upwards. A passing car would cast a shadow over the sensor, and that should be sufficient to trigger the circuit reliably.

A solution as simple as this is not always possible though, and some applications require the broken light beam approach. This is the type of thing featured in numerous heist movies and television programmes, where a beam of light or infrared is transmitted from one side of a room, or corridor, to a sensor on the other side. The sensor circuit detects the lack of light if someone breaks the beam, and the alarm is them sounded.

Systems of this type are not restricted to detecting people, or to other applications that operate on a relatively large scale. Taking an RPM meter as an example again, a spinning disc with a small hole drilled in it could be used in conjunction with an LED light source and a phototransistor fitted either side of the disc. An output pulse would be generated each time the hole passed between the light source and the detector.

Getting focused

Operation at long ranges can be difficult due to problems with the ambient light swamping the light from the system's light source. Shielding the sensor from the ambient light helps, and placing a tube in front of it to narrow the angle of view can make a further improvement.

For reliable operation at distances of several metres or more, it will be necessary to use a more sophisticated optical system. In particular, it is necessary to have the light source properly focused into a narrow beam of light. With no focusing of the light source, or if it is loosely focussed into a beam that allows the light to spread significantly, the intensity of the light will drop away quite rapidly as the distance from the source increases.

A focussed light source could be something as simple as a torch. These mostly focus the light into a tight enough beam to give good results, but some work much better than others in this application. The more sophisticated approach is to use a lens at the transmitter, and possibly at the sensor end as well. Two positive (convex) lenses are needed for optimum results, and they are used in the arrangement shown in Fig.2.

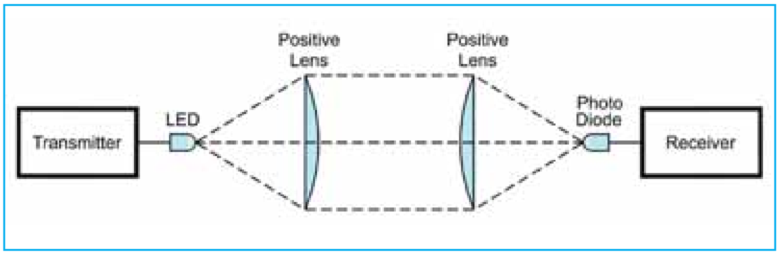

Fig.2. Adding a simple lens system can greatly increase the maximum operating range of an optical detector. Everything has to be accurately set up and aligned or the system will fail to work

The exact diameter and focal lengths of the lenses are not critical, but a diameter of around 30mm to 40mm is large enough to give good results, without making the system large and cumbersome. Smaller lenses might not give worthwhile results.

The system will be accurately focused when the distance between the lens and the emitting or detecting device is equal to the focal length of the lens. A long focal length is undesirable because it requires the two units to be quite large. Also, in the case of the transmitter, having a long focal length means that the light from the emitting device will spread and be relatively weak by the time it reaches the lens.

Small magnifying glasses should work quite well if nothing more suitable can be found. If the focal length of the lens is unknown, it is not difficult to measure it.

On a cloudy day, go outside and hold the lens above a piece of card. Provided the lens is a positive type, it should be possible to project an image of the sky onto the card. With the image properly focused, the distance from the lens to the card is equal to the focal length of the lens.

The emitting device will usually be some form of LED, and one having a built-in lens that concentrates its light output over a relatively narrow angle is likely to give better results than one that spreads its light over a wide angle. If a lens is used at the receiving end of the system, it does not matter too much whether the light sensing device is a plain type or has a built-in lens.

Either way, the main lens will concentrate the received light onto the opto-detector and give a major boost to performance. In addition to making the receiving unit more directional with a very narrow angle of view, a lens should give a massive increase in sensitivity by gathering light over a relatively large area and concentrating it onto the sensing device.

Greatly extended range can be obtained by using two lenses with everything adjusted for optimum results. However, bear in mind that both the transmitting and receiving units will be highly directional, which can make it difficult to get them aimed at each other with adequate accuracy.

Getting everything set up correctly can be especially difficult if an infrared transmitter is used, because you cannot see its 'light' output, and cannot be sure where it is aimed. Defocusing the two units very slightly will reduce the maximum operating range, but it can make it much easier to get the two units optically aligned.

On reflection

Another way of using an optical sensor is to have it detect reflected light. This type of thing can work well at short distances and in a controlled environment, but it is not usually practical at long ranges, due to insufficient reflected light for the sensor to detect.

Once again, using an RPM meter as an example, this is the type of application where a reflected light sensor can work well. The rotating disc or shaft could be light in colour with a spot of black paint added, or dark in colour with a spot of white paint added.

In either case, the sensor should be able to detect the change in light level each time the spot of paint passes by. The sensing device should preferably be one that has a built-in lens, and it would need to be quite close to the disc or shaft. Obviously, there must be a reasonable amount of light present for the system to work properly, but a high-brightness LED should be adequate as the light source if the ambient light is insufficient.

On the pulse

The main limitation of a simple optical sensor is that in practical situations there will often be little difference between the background light level and the amount of light reflected from what you are trying to detect. In the right circumstances it will work well, but in many situations it will not work at all or will be unreliable.

In difficult situations, it is usually, better to use a pulsed system. The transmitter pulses an LED at a frequency that is typically a few kilohertz. The receiver greatly amplifies the pulses from the sensing element, rectifies and smoothes them to produce a DC signal, and then feeds the resultant DC signal to a level detector.

With a reasonably strong signal received, there will be a relatively high DC voltage and the output of the level detector will be sent to the relevant output state. With a weak signal received, or no pulse signal at all, a very low DC voltage will be produced and the output of the level detector will go to the opposite state.

The beauty of this system is that the ambient light level is largely irrelevant because the receiver only responds to pulses of light, and is unaffected by any normal changes in the ambient light level. It works just the same in total darkness or under bright conditions. The sensing device must not be subjected to such strong ambient light that it becomes saturated and ceases to work properly, but beyond that the ambient light level is unimportant.

The circuit diagram for a simple pulsed transmitter is shown in Fig.3. This is basically just a 555 timer device used in the standard astable (oscillator) configuration. It produces a roughly square wave output signal at just under 7kHz.

Transistor TR1 acts as a buffer stage at the output, so that infrared LED D1

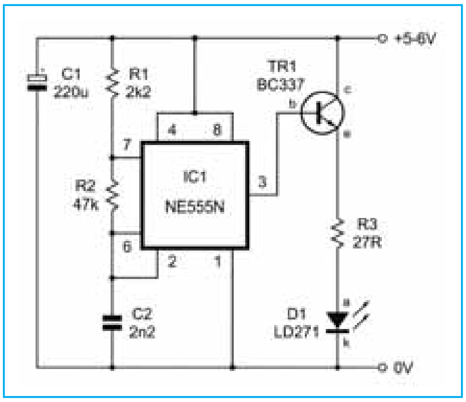

Fig.3. The pulsed transmitter is basically just a 555 oscillator with a buffer stage (TR1) to drive an infrared LED (D1). Systems of this type can work in the visible light spectrum, but using infrared devices usually gives better results

can be supplied with the relatively high drive current of about 75mA. The average current supplied to D1 is about half this, as it is switched off for about 50 percent of the time.

IC1 is specified as a 555 timer, but the circuit should work equally well using a low-power or otherwise improved version of the 555. Practically any infrared LED for remote controls and similar applications should suffice for D1. The system would probably work quite well using a visible light emitter and sensor, but infrared devices are generally preferred for this type of thing.

Receiver

The receiver circuit appears in Fig.4. D1 is the detector, and it is reverse biased by resistor R1. The pulses of infrared from the transmitter increase the

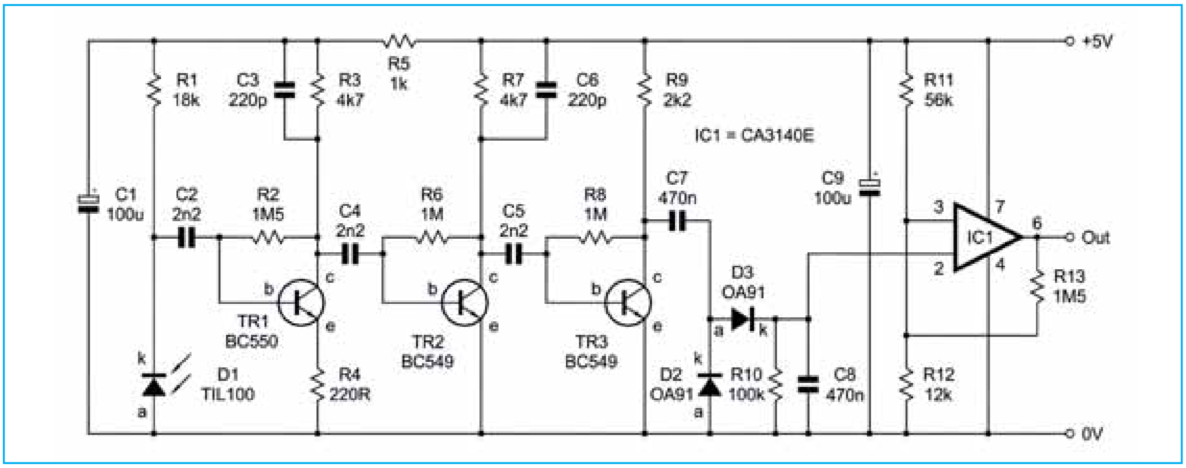

Fig.4. The circuit for the receiver circuit has a high gain amplifier using three transistors (TR1 to TR3). Due to its high gain, the layout of the circuit must be designed with due care if problems with instability are to be avoided

leakage level through D1, producing small voltage variations at its cathode (k) terminal. These are amplified by a high-gain, three-stage amplifier based on TR1, TR2, and TR3.

A rectifier and smoothing circuit, using diodes D2 and D3, produces a positive DC signal that drives a simple Schmitt trigger/level detector circuit based on op amp comparator IC1. The output of IC1 is low when the signal from the transmitter is detected properly, and high when it is not.

Any infrared diode for remote control applications should be suitable for D1, and for some applications a type having an integral lens would be preferable. Germanium diodes, with their lower forward voltage drop are preferable for D2 and D3, but silicon types such as the 1N4148 or 1N914 would probably work well enough.

Capacitors C3 and C6 aid the stability of the circuit by reducing the gain at high frequencies, but the layout of the circuit needs to be carefully designed if problems with stray feedback and oscillation are to be avoided. The op amp comparator used in the IC1 position is a type that requires the usual anti-static handling precautions. IC1 pin 2 and pin 3 are inverting and non-inverting respectively.

Sensitivity

Even with no additional lenses used, it should be possible to obtain reliable operation in broken beam applications at ranges of several metres. Using a good twin lens system it is possible to obtain ranges of a few hundred metres using a system of this type, but getting the system aligned properly at long ranges can be problematic.

The maximum range obtained in a reflected light application depends to a large extent on the object being detected, distances of two metres or so are achievable using emitting and receiving diodes having built-in lenses. Much higher ranges are possible using additional lenses.

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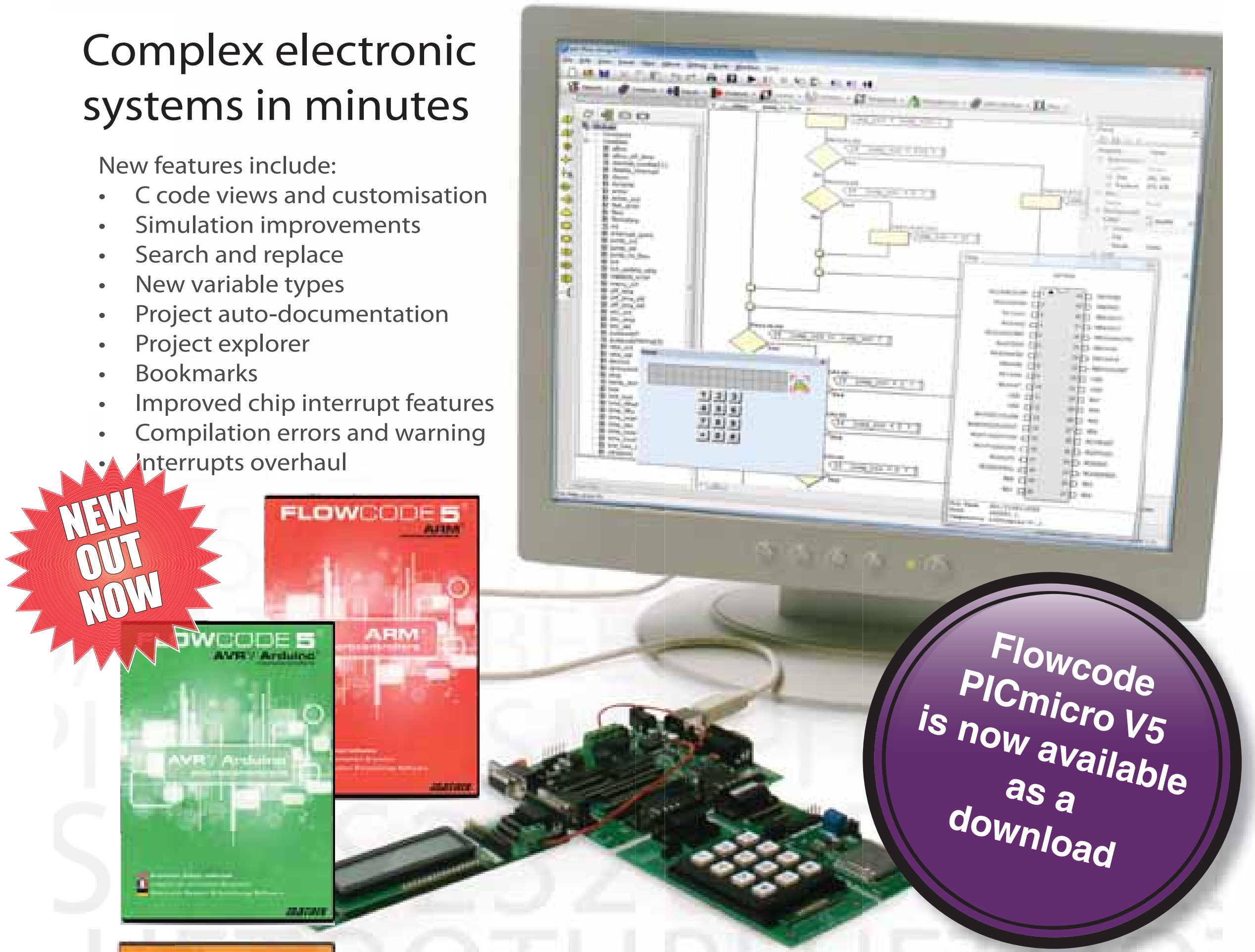

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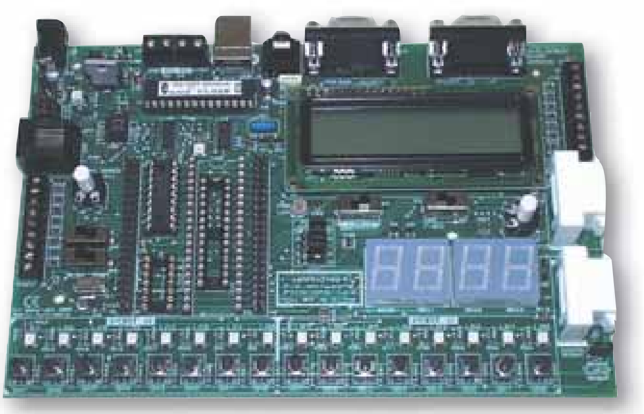

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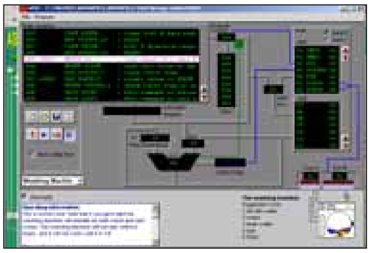

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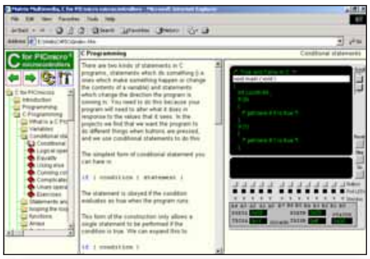

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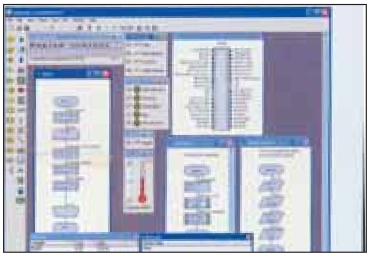

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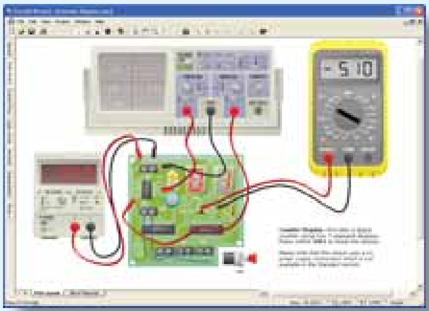

This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

Standard **£61.25** inc. VAT
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Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

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- PIC Toolkit Mk3 (TK3 hardware construction details), John Becker, Oct '01
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NET WORK

by Alan Winstanley

We come in peace

YOU are now sharing in the space technology that put man on the moon and will lead him to the stars. This Time Computer is supremely accurate and its other incredible features are detailed in the following pages of this booklet.' Those were the opening words in the tiny manual printed on laid paper that accompanied a 1970s LED digital wristwatch that I acquired recently. Powered by two 1.5V button cells, the LED watch solely displays the time, day and date at the press of a button, and its multiplexed red display is invisible in sunlight. The booklet recommended that owners take a spare set of cells with them on holiday, just in case, and it gushed that 'This is the beginning, you are now a participant on the vast and ever expanding frontiers of space technology.' The electronics module was made by Hughes Microelectronics Ltd of Glenrothes in Scotland, reflecting the heady days of the 1970s when new electronics industries sprang up in the UK, attracted by Government grants, only to disappear just as quickly in the years afterwards.

Getting curious: the first full-resolution image of Mars sent by Curiosity. Gale Crater is in the distance. The two distinct patches in the foreground were probably caused by descent thrusters. (Courtesy NASA/JPL-Caltech)

Hyperbole aside, the star-struck aspirations of that era were not at all unfounded. On the 6 August 2012, in a scene straight out of *Thunderbirds*, NASA celebrated the astonishing feat of lowering the Mars Science Laboratory (MSL) vehicle 'Curiosity' gently onto the surface of Mars. The world held its breath during the seven critical minutes preceding touchdown, and Internet users could see some of the action online on NASA TV, though the surge of web traffic blocked some viewers from witnessing this milestone in space exploration in real-time. The three BAE Systems radiation-hardened computers on board MSL could not be further removed from the Hughes 1,500-transistor chip nestling inside my 'space-age' LED watch.

Martian curiosity

The main website portal for the MSL is **http://mars.jpl.nasa.gov/msl** and NASA TV offers UStream on-screen video, as well as feeds for iOS and Android mobile devices. At the time of writing, a few hours after touchdown, there's a monochrome photo of a wheel captured by Curiosity's cameras, and a stop-frame colour movie of the descent showing the retro-rockets firing. What a fantastic achievement! The best has yet to come, so here's to the success of Curiosity's next two years exploring the Martian landscape.

NASA's provision of video feeds for mobile devices reflects the fact that many Internet users no longer rely on needing a PC or laptop tethered to a router. In bygone days, we would glean news of the space programme on a grainy monochrome TV, and if you wanted a memento of the moon landings you could buy a set of 35mm colour transparencies by mail order.

With a new generation of interesting mobile devices now readily available, it's becoming second nature to check a mobile or tap a tablet in order to see Curiosity's progress, maybe check an email or browse a website or two, post on Facebook or even turn down the room lights using an app on your phone or tablet. With the focus ever more on mobile surfing, even an older mobile phone can benefit from Opera, a slim and neat web browser that makes the web more usable in many respects. You can download Opera Mobile or Opera Mini from **www.opera.com/mobile**. Opera Mobile 12 also supports Flash on the Android platform and I found that Opera Mini installed on a Windows Mobile phone with no fuss whatsoever. If you're looking for an alternative and altogether slicker way to browse the web, then Opera may be for you.

The trend towards mobile networking begs the question of the future roles of desktop PCs and laptops. I believe that it's simply 'horses for courses', with the latest breed of tablets playing a role as a very convenient way of keeping on top of email, web, news and social networking around the house or office, bolstered by a bonanza of apps costing a few pennies. If you want a lightweight device with Qwerty keyboard instead, then an Intel-based Ultrabook might be ideal, but they're very pricey.

NASA multimedia snapshot of Curiosity Mars Science Laboratory (MSL) descending onto Mars on 5 August 2012 (PDT)

Personally speaking, I could not research and write *Net Work* on a tablet, but I might use one to write part of it while stuck on the train. The desktop PC can be viewed as a trusty workhorse or a domestic appliance suited to intensive

surfing, editing, DVD burning, printing, accounts, graphics and more: you might watch Internet-sourced movies on it or you will probably prefer to use a tablet, Internet appliance or console such as the Xbox 360 or 720 to view Internet movies that way instead.

Seven-year itch

According to the old adage, if you keep a thing for seven years you will always find a use for it. Earlier this year, I mentioned how Microsoft Windows 7 was finally making its way into my worklab. Mindful of the fact that Windows XP (now more than a decade old) was starting to creak at the seams, I felt that the time was ripe for switching to the newer OS. So it was with some uncertainty that I opted to upgrade a faithful PC (desperately in need of an overhaul) to Windows 7 Professional. Apart from anything, this would allow Windows Internet Explorer 9 to run, but Windows 7 would also introduce other benefits, such as very rapid boot up and shut-down times and many shortcomings of XP would also be removed.

I chose the 32-bit version, as befits my hardware, but a clean new Samsung 1TB hard disk was the only concession made to the new installation. Windows 7 slipped into place on my 3GHz PC without a hitch and connected straight away to the router to download patches and updates. The vast majority of my software library also re-installed successfully, including my faithful Eudora email program. It may seem like an anachronism, but this friendly and feature-rich email program was soon up and running, directly importing my entire mail folder from XP. I used the excellent Advanced Uninstaller Pro, free from Innovative Solutions at **www.advanceduninstaller.com** to remove an errant program.

On the downside, all of my legacy printers and scanners would only operate using Windows 7's built-in drivers, so some functionality has been lost, and a very small number of weird and wonderful programs (eg, the PC's overclocking and fan control software devised for XP) would not install at all, despite trying various Compatibility modes. Otherwise, setting up a network in Windows 7 was easier than ever before.

Thanks to the web, most troublespots were ironed out (a recommended forum is **www.sevenforums.com**). Even obscure hardware, such as a beloved Palm Tungsten PDA worked, Bluetooth installed perfectly, and Windows 7 had some nice tricks up its sleeve – connecting a large Wacom graphics tablet automatically installed Windows 7's Pen and Touch applet, along with handwriting recognition.

The older PC hardware can slow a little under the rigours of intensive surfing and there's no doubt that IE9 gobbles more than its fair share of resources. In contrast, Firefox 14 loads in half the time (say one second) and has proven more productive than ever before. Another 'gotcha' was IE9's inability to upload files over the web. An exception rule was needed for the local Intranet zone as follows (Tools/ Internet Options/ Security / Local Intranet / Sites / Advanced): Allow websites: **file://net30** (net30 being the network name of my PC). Firefox had no such file-blocking problem.

A more strategic reason for upgrading to Windows 7 right now is that I'm confident that it will offer a stable, high quality platform that will serve me well for years to come, just as Windows XP has done. Several software and hardware trends are presently converging, which means that IT users and Internet enthusiasts will face some key choices in coming months. For XP users who want to breathe some life into their system, now is a good time to update to Windows 7: it's a very stable, thoroughly sorted and very usable interface which runs fine on many older PCs, and plenty of peer help is available online.

A key event in the IT calendar is the arrival of Windows 8 in October. The two-dimensional tiled Start Screen of Windows 8 was crafted with touchscreen users in mind and may be a nuisance for seasoned users. Many PC and laptop owners may see Windows 8 as a step too far, and Windows 7 may be the optimal upgrade at this point in time. Note that Windows RT is a 'lighter' version of Windows 8 designed for the ARM processors found in many new mobile products.

Surfing on the Surface

It's not only operating systems that are coming under the microscope. Interesting hardware releases for mobile users include the Microsoft Surface, an intriguing and eagerly anticipated super-slender Windows computer with 10.6-inch HD screen, a detachable 3mm cover and built-in kickstand. The cover also happens to be a pressure-sensitive keyboard and trackpad. It holds in place with a single magnetic click, and a separate slightly thicker (5mm) Type Cover will enable more conventional laptop-style use with a proper Qwerty keyboard instead. Surface will arrive at the same time as Windows 8 and is Microsoft's first own-brand computer. It's being touted as an ultrabook alternative, so it won't be cheap. More details at: **www.surface.com**.

Microsoft's new Surface with prop-stand and detachable pressure-sensitive keyboard and cover is Microsoft's first in-house Windows computer. The flat tiled styling of the Windows 8 Start Screen is aimed firmly at touch screen and tablet users

There is no news from Amazon and its Kindle Fire colour device is still not available in the UK. Google's Nexus 7 is their own-label entry to the hotly contested tablet market. It's a 7-inch (diagonal) device running the latest variant of Google's Android 4.1 (Jelly Bean). Internal memory is 8GB or 16GB, which cannot be expanded, with a list price of £159 or £199 respectively. Included are 802.11n, Bluetooth, NFC, GPS and USB. Search **https://play.google.com/store/devices** for details.

If you're a *Hotmail* user then you will want to head over to Microsoft's new **Outlook.com** website. Outlook is Microsoft's answer to Google Gmail and the service is currently ramping up to speed. With a clean and uncluttered interface, Outlook is easy to use and apart from running over the web may also be used in some popular POP and IMAP email clients (sadly, my Eudora 7 is not one of them). Readers looking for a new email address should compare it with Gmail and register their choice of username on **Outlook.com** before someone else does.

I hope you found something of interest in this month's *Net Work*. I apologise to those who have tried contacting me through my traditional Demon Internet email address. This has been adversely affected for several months by Demon's rolling update program and a significant number of legitimate emails have bounced back as undeliverable. As always, emails are welcome to **alan@epemag.demon.co.uk** and you can also share your views with the editor at **editorial@wimborne.co.uk**.

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ELECTRONICS TEACH-IN BUNDLE – SPECIAL BUNDLE PRICE £14 FOR PARTS 1, 2 & 3

ELECTRONICS TEACH-IN 2 CD-ROM
USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers. An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

The Microchip items are: MPLAB Integrated Development Environment V8.20; Microchip Advance Parts Selector V2.32; Treelink; Motor Control Solutions; 16-bit Embedded Solutions; 16-bit Tool Solutions; Human Interface Solutions; 8-bit PIC Microcontrollers; PIC24 Mircrontrollers; PIC32 Microcontroller Family with USB On-The-Go; dsPIC Digital Signal Controllers.

CD-ROM — **Order code ETI2 CD-ROM** — £9.50

FREE CD-ROM

ELECTRONICS TEACH-IN 3

The three sections of this book cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on various circuit design and application problems – everything from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered. Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 circuit designs submitted by the readers of *EPE*.

The free cover-mounted CD-ROM is the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial), together with simulations of the circuits in the Teach-In 1 series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC. There is also a MW/LW Radio project in the series. The contents of the book and Free CD-ROM have been reprinted from past issues of *EPE*.

160 pages — **Order code ETI3** — £8.50

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The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

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J.G. Lee

Radio wave propogation is one of the more important discoveries made in the early 20th century. Although technology lagged behind early experimenters pursued this newly discovered phenomenon eagerly for, in understanding the physics of propagation, they were discovering more about our Universe and its workings.

Radio wave propagation has its origins in the world of solar physics. The Sun's radiation provides the mechanism for the formation of the ionosphere. How the ionosphere is formed, and how it provides long-distance communication, is carefully explained. Non-ionospheric propagation, including 'moonbounce' or satellite communications, is covered as well.

This book has been written with the average electronic hobbyist in mind. Technical language and mathematics have been kept to a minimum in order to present a broad, yet clear, picture of the subject. The radio amateur, as well as the short-wave listener, will find explanations of the propagation phenomena which both experience in their pursuit of communications enjoyment.

116 pages — **Order code BP293** — £4.45

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E. A. Parr

Every so often a device appears that is so useful that one wonders how life went on before without it. The 555 timer is such a device. Included in this book are over 70 circuit diagrams and descriptions covering basic and general circuits, motor car and model railway circuits, alarms and noise makers as well as a section on 556, 558 and 559 timers. (Note. No construction details are given.) A reference book of invaluable use to all those who have any interest in electronics, be they professional engineers or designers, students or hobbyists.

167 pages — **Order code BP44** — £5.49

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This book explains the basic function of an oscilloscope, gives a detailed explanation of all the standard controls, and provides advice on buying. A separate chapter deals with using an oscilloscope for fault finding on linear and logic circuits, plenty of example waveforms help to illustrate the control functions and the effects of various fault conditions. The function and use of various other pieces of test equipment are also covered, including signal generators, logic probes, logic pulsers and crystal calibrators.

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R. A. Penfold

This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:

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In fact everything you need to know in order to get started in this absorbing and creative hobby.

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Jim Gatenby

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THEORY AND REFERENCE

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Second Edition
Clive (call me Max) Maxfield

This book gives the "big picture" of digital electronics. This in-depth, highly readable, guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more. The author's tongue-in-cheek humour makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate.

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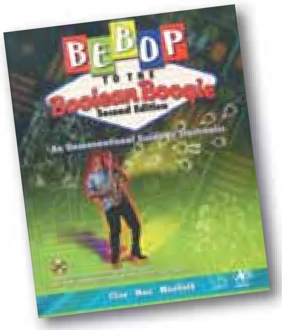

BEBOP BYTES BACK (and the Beboputer Computer Simulator) CD-ROM
Clive (Max) Maxfield and Alvin Brown

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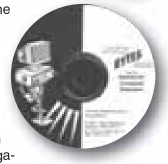

This follow-on to Bebop to the Boolean Boogie is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the CD-ROM contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the CD-ROM contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. If you're the slightest bit interested in the inner workings of computers, then don't dare to miss this!

Over 800 pages in Adobe Acrobat format

CD-ROM **Order code BEB2 CD-ROM** **£21.95**

INTERFACING PIC MICROCONTROLLERS
Martin Bates

An essential guide to PIC interfacing techniques, using circuit simulation to aid learning.

Explore in detail microcontroller interfacing techniques using the popular PIC 16F877. Work through step-by-step examples interactively using circuit simulation software, supplied as assembly source code.

Interfacing PIC Microcontrollers provides a thorough introduction to interfacing techniques for students, hobbyists and engineers looking to take their knowledge of PIC application development to the next level. Each chapter ends with suggestions for further applications, based on the examples given, and numerous line drawings illustrate application of the hardware.

Step-by-step examples in assembly language are used to illustrate a comprehensive set of interfaces, and these can be run interactively on circuit simulation software, used to aid understanding without the need to build real hardware.

A companion website includes all examples in the text which cam be downloaded together with a free version of Proteus's ISIS Lite.

298 pages **Order code NE48** **£30.99**

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold

This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.

In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

102 pages **Order code BP239** **£5.49**

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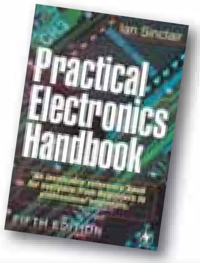

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All modern music recordings use digital audio technology. Now everyone with a compouter can produce CD-quality recordings and this book shows you how. Written in a clear and straightforward style, it explains what digital audio recording is, how to use it, the equipment you need, what sort of software is available and how to achieve professional results.

Computer-based recording is the future of music and this book shows how you can join the revolution now.

208 pages **Order code PC121** **£7.95**

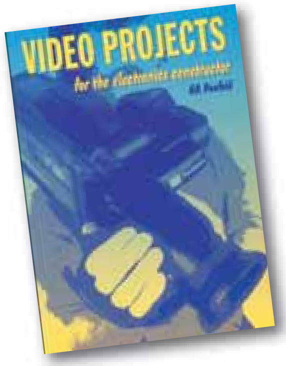
QUICK GUIDE TO MP3 AND DIGITAL MUSIC
Ian Waugh

MP3 files, the latest digital music format, have taken the music industry by storm. What are they? Where do you get them? How do you use them? Why have they thrown record companies into a panic? Will they make music easier to buy? And cheaper? Is this the future of music?

All these questions and more are answered in this concise and practical book which explains everything you need to know about MP3s in a simple and easy-to-understand manner. It explains:

How to play MP3s on your computer; How to use MP3s with handheld MP3 players; Where to find MP3s on the Web; How MP3s work; How to tune into Internet radio stations; How to create your own MP3s; How to record your own CDs from MP3 files; Other digital audio music formats.

Temporarily out of print



ELECTRONIC PROJECTS FOR VIDEO ENTHUSIASTS
R. A. Penfold

This book provides a number of practical designs for video accessories that will help you get the best results from your camcorder and VCR. All the projects use inexpensive components that are readily available, and they are easy to construct. Full construction details are provided, including stripboard layouts and wiring diagrams. Where appropriate, simple setting up procedures are described in detail; no test equipment is needed.

The projects covered in this book include: Four channel audio mixer, Four channel stereo mixer, Dynamic noise limiter (DNL), Automatic audio fader, Video faders, Video wipers, Video crispener, Mains power supply unit.

109 pages **Order code BP356** **£5.45**

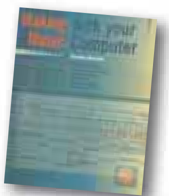
MAKING MUSIC WITH YOUR COMPUTER
Stephen Bennett

Nearly everyone with musical aspirations also has a computer. This same computer can double as a high quality recording studio capable of producing professional recordings. This book tells you what software and hardware you will need to get the best results.

You'll learn about recording techniques, software and effects, mixing, mastering and CD production.

Suitable for PC and Mac users, the book is full of tips, "how to do" topics and illustrations. It's the perfect answer to the question "How do I use my computer to produce my own CD?"

92 pages **Order code PC120** **£10.95**



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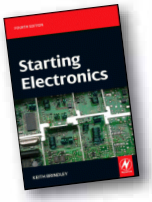
FAULT FINDING, CIRCUITS AND DESIGN

STARTING ELECTRONICS – 4th Edition
Keith Brindley
A Starting Electronics is unrivalled as a highly practical introduction for technicians, non-electronic engineers, software engineers, students, and hobbyists. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits. Breadboard layouts make this very much a ready-to-run book for the experimenter, and the use of readily available, inexpensive components makes this practical exploration of electronics easily accessible to all levels of engineer and hobbyist.

Other books tell readers what to do, but sometimes fail to explain why – Brindley gives readers hands-on confidence in addition to real scientific knowledge, and insight into the principles as well as the practice. All written explanations and steps are supplemented with numerous photos, charts, tables and graphs. Concepts and practical aspects are explained thoroughly with mathematical formulae and technical schematic drawings.

Each chapter introduces a concept or tool, explains the basic theory, and provides clear instructions for a simple experiment to apply the concept or tool, with quiz sections and answers, at the end of each chapter.

296 pages **Order code NE100** **£18.99**



HOW ELECTRONIC THINGS WORK – AND WHAT TO DO WHEN THEY DON'T
Robert Goodman
You never again have to be flummoxed, flustered or taken for a ride by a piece of electronics equipment. With this fully illustrated, simple-to-use guide, you will get a grasp on the workings of the electronic world that surrounds you – and even learn to make your own repairs.

You don't need any technical experience. This book gives you: Clear explanations of how things work, written in everyday language. Easy-to-follow, illustrated instructions on using test equipment to diagnose problems. Guidelines to help you decide for or against professional repair. Tips on protecting your expensive equipment from lightning and other electrical damage, lubrication and maintenance suggestions.

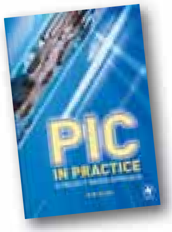
Covers: colour TVs, VCRs, radios, PCs, CD players, printers, telephones, monitors, camcorders, satellite dishes, and much more!

394 pages **Order code MGH3** **£21.99**

PIC IN PRACTICE (2nd Edition)
David W. Smith
A graded course based around the practical use of the PIC microcontroller through project work. Principles are introduced gradually, through hands-on experience, enabling hobbyists and students to develop their understanding at their own pace. The book can be used at a variety of levels.

Contents: Introduction to the PIC microcontroller; Programming the 16F84 microcontroller; Introductory projects; Headers, porting code – which micro?; Using inputs; Keypad scanning; Program examples; The 16C54 microcontroller; Alphanumeric displays; Analogue to digital conversion; Radio transmitters and receivers; EEPROM data memory; Interrupts; The 12 series 8-pin microcontroller; The 16F87X microcontroller; The 16F62X microcontroller; Projects; Instruction set, files and registers; Appendices; Index.

308 pages **Order code NE39** **£24.99**

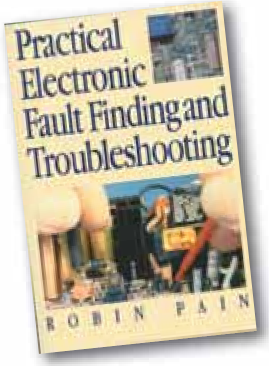


PRACTICAL ELECTRONIC FAULT FINDING AND TROUBLESHOOTING
Robin Pain
To be a real fault finder, you must be able to get a feel for what is going on in the circuit you are examining. In this book Robin Pain explains the basic techniques needed to be a fault finder.

Simple circuit examples are used to illustrate principles and concepts fundamental to the process of fault finding. This is not a book of theory, it is a book of practical tips, hints and rules of thumb, all of which will equip the reader to tackle any job. You may be an engineer or technician in search of information and guidance, a college student, a hobbyist building a project from a magazine, or simply a keen self-taught amateur who is interested in electronic fault finding but finds books on the subject too mathematical or specialised.

The fundamental principles of analogue and digital fault finding are described (although, of course, there is no such thing as a "digital fault" – all faults are by nature analogue). This book is written entirely for a fault finder using only the basic fault-finding equipment: a digital multimeter and an oscilloscope. The treatment is non-mathematical (apart from Ohm's law) and all jargon is strictly avoided.

274 pages **Order code NE22** **£41.99**



AUDIO AMPS

BUILDING VALVE AMPLIFIERS
Morgan Jones
The practical guide to building, modifying, fault-finding and repairing valve amplifiers. A hands-on approach to valve electronics – classic and modern – with a minimum of theory. Planning, fault-finding, and testing are each illustrated by step-by-step examples.

A unique hands-on guide for anyone working with valve (tube in USA) audio equipment – as an electronics experimenter, audiophile or audio engineer.

Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout.

368 pages **Order code NE40** **£29.00**

VALVE AMPLIFIERS
Second Edition. Morgan Jones
This book allows those with a limited knowledge of the field to understand both the theory and practice of valve audio amplifier design, such that they can analyse and modify circuits, and build or restore an amplifier. Design principles and construction techniques are provided so readers can devise and build from scratch, designs that actually work.

The second edition of this popular book builds on its main strength – exploring and illustrating theory with practical applications. Numerous new sections include: output transformer problems; heater regulators; phase splitter analysis; and component technology. In addition to the numerous amplifier and preamplifier circuits, three major new designs are included: a low-noise single-ended LP stage, and a pair of high voltage amplifiers for driving electrostatic transducers directly – one for headphones, one for loudspeakers.

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For a further selection of books see the next two issues of *EPE*.
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READOUT

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

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An Atlas LCR Passive Component Analyser, kindly donated by Peak Electronic Design Ltd, will be awarded to the author of the Letter Of The Month. The Atlas LCR automatically measures inductance from 1mH to 10H, capacitance from 1pF to 10,000µF and resistance from 1Ω to 2MΩ with a basic accuracy of 1%. www.peakelec.co.uk

All letters quoted here have previously been replied to directly

Email: editorial@wimborne.co.uk

☆ LETTER OF THE MONTH ☆

The next generation of electronic engineers

Dear Mr Winstanley
I found your article: 'Interview 2: A Voyage on Veroboard', fascinating. [see **http://alanwinstanley.com**, where Alan is publishing his old projects from 1978 onwards, plus photos of the prototypes and other 'ramblings'. – Ed] I think it's great that you are publishing your old work – I see so many potentially useful resources that have just fallen by the wayside, or tutorials that never got finished.

I am a lower-sixth student, and have been an *EPE* reader for the last few years (and sporadically when I was younger – too young to understand much, my dad has several issues from the 70/80s).

I find it incredible that all these years later, the syllabus for my 'A' level in electronics has changed little from designs you submitted to *PE*/*EPE* so long ago. One that particularly caught my eye was a delay switch. The monostable circuit you use is exactly what we are taught today – and still using the 555!

Of course, there has been progress on the syllabus, such as PIC programming (though only recently did the recommended device switch from the 16C84 to the 16F84A; simply because the C84 was no longer available). It is though, reassuring to know that techniques we're taught are tried and tested – after all, if it ain't broke...

Over the years, *EPE* has been hugely helpful to my school studies, as well as my interests outside. I think it's important to read around subjects on which you'll be assessed, and *EPE* definitely works for me. I've suggested it as reading to everyone else on the course and even left a copy in the lab!

I think it is in some ways unfortunate that the electronics industry has reached a point where no one person can possibly understand 'everything', you can understand the very basics of a broad base, or a lot about one aspect of one small thing. For example, I watch films such as *Pirates of Silicon Valley*, and *Wargames* – and wish that I had grown up in a time when one (or two) young people could scratch-build a working computer (at least as they were at the time).

Of course, I could (potentially) work on a project to build a PC of that era, as shown on **www.homebrewcpu.com**, but the point is PCs have become so advanced that I couldn't possibly design all the electronics for a modern one. I could (and have) built one from existing components, but that's just not quite the same as hard-wiring individual transistors. One engineer or hobbyist just can't compete against industry's 28nm manufacturing process!

It worries me that fewer and fewer people of my generation seem to take an interest in electronics or computer science. In an age when we're so reliant on electronic products, I can't understand why more people don't wish to study them. I hope that groups such as the Raspberry Pi Foundation and Computing At School will succeed in rekindling interest.

Anyway, please keep up the excellent work, I must sign off now to read the latest edition, which landed on my doormat today.

Ollie Ford, by email

Alan Winstanley replies:

Dear Oliver
I read your email with great pleasure and wanted to thank you for taking the time to share your views with me. It's great to see such enthusiasm for EPE *carrying through to the next generation!*

I'm very close to uploading the next stage of my 'voyage' on to my own website (next day or two hopefully), and this will be a bumper update featuring many more of my projects from the era that are still remembered to this day. There is still a lot in the pipeline to write about (I'm less than half-way through), and I'm only surprised that I managed to get through all that work at the time!

I will also be publishing on the web a master list of all my projects, linked to article reprints.

Alan Winstanley, EPE online editor

Readers can contact Alan by email at: alan@epemag.demon.co.uk

Stripboard request

Dear editor
I have a couple of things I want to ask about. My most important (to me, at least) request is that you do a few stripboard layouts every now and then, like the ones you used to carry. I know it isn't feasible to do them all the time because they quite often take longer than laying out a PCB, but it's nice to have a quick circuit to build when you get a new magazine. The alternative is buying a PCB and waiting for it to arrive, sometimes from Australia, which of course takes ages, by which time you can lose momentum for a particular project.

I have an online 'blogsite' where I post stripboard layouts for people wanting to learn, as well as things I thought were cool or that I designed myself. (Note that I do always build them before I post them, because there is nothing worse than building something that you're not sure has been properly tested and might not even work.) You can find the site at: **http://paulinthelab.blogspot.co.uk**

My second point is Max needs to go back to writing good articles that don't involve Apple iPads/products. I used to enjoy his articles, but now I feel as though his blog has turned into an Apple advert. I'm not anti-Apple, I think the iPod is one of the best music players on the market, but I feel as though we have been bombarded enough by Apple advertising.

Paul Stevenson, by email

Matt Pulzer replies:

Hi Paul
Many thanks for the feedback. I appreciate your request for stripboard articles, but I do fear it is rapidly becoming 'yesterday's' technology when it comes to published projects. I can't remember the last time a stripboard project was submitted to us, but it must have been quite a while ago. As you can

see from our current beginners series – Jump Start – the advantages of using even a cheap and 'simple' computer design package like Circuit Wizard are considerable.

I'm not saying 'never' again, but we don't have any plans right now to publish a stripboard project. That said, I do like your website – perhaps you would like to submit one of your original projects (stripboard design included) to Ingenuity Unlimited!

I do understand your feeling about Apple saturation. Their products do seem to be everywhere. That said, EPE is pretty much Apple free; projects, software and Net Work are by and large PC oriented. So I hope you can indulge Max if he occasionally gets enthusiastic about his iPad!

Sourcing Australian parts

Dear editor

In EPE the projects are fantastic for the novice and professional alike, but components that are illustrated and used for some projects are hard to come by in the UK. Some projects are copyright to Silicon Chip, which since it is an Australian magazine, means parts are best obtained from there.

The parts list shows an item code, and then has a Jaycar code. Sourcing parts from Jaycar means an increase in price, compared to the UK – postage being one reason. I recently built a project and a problem I ran into was I could not source in the UK the listed LCD display – part number QP-5512 or equivalent.

The LCD that I've always used is Displaytech 1602B. I've tried other LCD models and none would work with the code supplied for the QP-5512. I've had some fantastic help from a forum member, but we are at a loss.

The QP-5512 is $19.95 (UK £13.91) + P&P, compared to below five pounds for the 1602B – a big price difference. Using Jaycar as the source makes them have the upper hand when it comes to parts purchasing. Sadly, it looks that if I do not purchase the component that is listed, then this project will stay unfinished.

In future, is it possible for project components to be UK sourced? Or can we have equivalent parts listed next to Jaycar's item? We have RS and Farnell as two major outlets and they would (hopefully) have the equivalent part.

Rich Cox, via email

Matt Pulzer replies:

Thank you for your letter Richard, and I'm glad you find the projects excellent. However, I am sorry to hear about your trouble in sourcing components. I appreciate it is easier to be wise after the event, but readers must always check that they can source parts – at a price that is acceptable to them – before starting a project.

We list Jaycar components because they are guaranteed to be correct. I do understand that in some cases prices may be higher, but by and large Jaycar are not expensive and shipping to Britain is speedy.

PCB SERVICE

CHECK US OUT ON THE WEB

Printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. All prices include VAT and postage and packing. Add £2 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail. Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

Please check price and availability in the latest issue. A large number of older boards are listed on, and can be ordered from, our website.

Boards can only be supplied on a payment with order basis.

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★Deluxe 3-Chan. UHF Rolling Code Remote Control – Transmitter	816 } pair	£12.43
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SEPTEMBER '11		
★ Digital Megohm and Leakage Current Meter	818	£9.72
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★ High-Quality Stereo DAC – Input & Control Board	820 } set	£20.41
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Twin Engine SpeedMatch Indicator	824	£8.75
★ Wideband Air/Fuel Display (double-sided)	825	£14.38
NOVEMBER '11		
★ Digital Capacitor Leakage Meter	826	£10.11
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– Rain Alarm (Sensor)	848 }	

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– Front Panel	852	£8.16
– LCD Meter	853	£7.19
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AUGUST '12		
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★ Electrolytic Capacitor Reformer And Tester	861	£16.71
★ Ultrasonic Cleaner	862	£8.75
High-power DC Motor Speed Controller – Non-Reversible	863	£6.50
– Reversible	864	£6.75
(Both boards double-sided)		
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★ Ultrasonic Anti-Fouling For Boats	866	£9.14
Jump Start – Versatile Theft Alarm	867	£9.33
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EPE SOFTWARE

★ All software programs for *EPE* Projects marked with a star, and others previously published can be downloaded free from the Library on our website, accessible via our home page at: **www.epemag.com**

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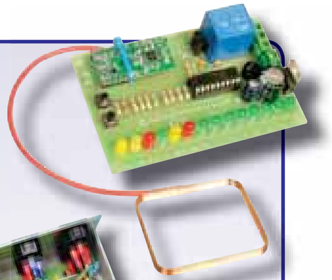
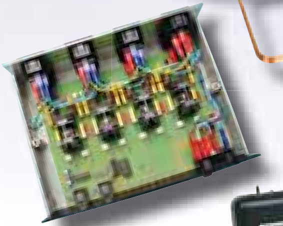
Next Month

Content may be subject to change



RFID Security System

Here's a high-security system that's very easy to build and offers you peace-of-mind for your home, car – in fact, anything where entry needs to allow the good guys in but reject the bad guys. Team it with an electric lock and you can have a keyless entry system as well!



Digital Lighting Controller – Part 2

Everyone who has seen the *Digital Lighting Controller* has been pretty impressed – and no wonder! While we originally intended it to make your Christmas lights display the best in your neighbourhood, it's actually capable of controlling just about any lighting sequencing task you want to throw at it. Now, in Part 2, we get on with the good stuff – putting it all together!

Hearing Loop Level Meter – Part 1

Setting the correct signal level and minimising noise are critical factors when setting up a hearing loop. This easy-to-build tester can display field strength levels over a 27dB range.

Easy USB review and Telescope Control

Two articles for the price of one! We describe a new and possibly unique product called 'Easy USB' by Brunning Software. It makes programming serial USB communication applications between your PC and a PIC-based peripheral simple.
As a practical example, we demonstrate an astronomical telescope drive system.

Jump Start

Next up with *Jump Start* in November's *EPE* is a *Frost Alarm*. This will be Mike and Richard Tooley's seventh project in our new series dedicated to newcomers, or those following courses taught in schools and colleges.

NOVEMBER '12 ISSUE ON SALE 4 OCTOBER 2012

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